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Federal Bureau of Investigation

Crime Laboratory Digest

Review Article In This Issue:

X-Ray Fluorescence Spectrometry

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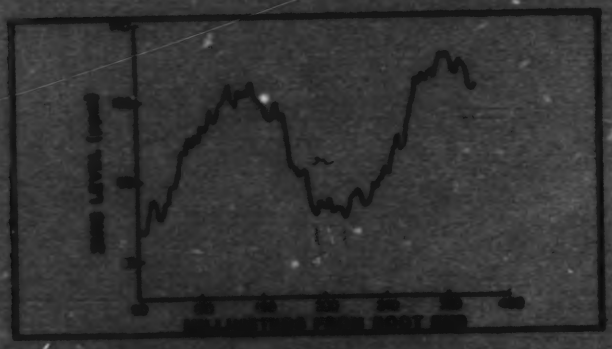

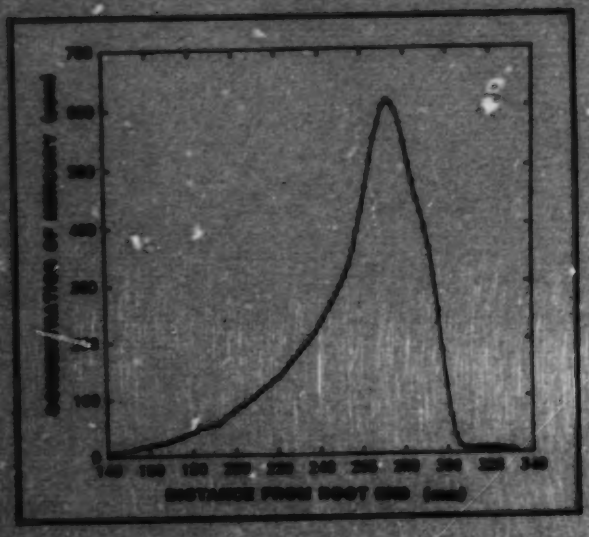

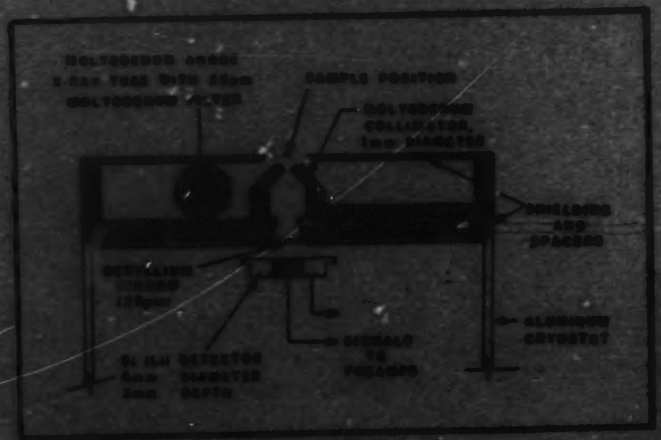

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The Crime Laboratory Digest is published quarterly by the FBI Laboratory in cooperation with the American Society of Crime Laboratory Directors (ASCLD). It is intended to serve as a rapid means of communication between crime laboratories, providing information of interest and value to be disseminated among crime laboratory scientists.

Inclusion of an article in the Crime Laboratory Digest in no way represents an endorsement or recommendation of any part of that article by the Federal Government, the Department of Justice or the FBI. Contributing authors assume total responsibility for the contents and accuracy of their submissions. Questions or requests concerning an article should be directed to the contributing agency.

All submissions are subject to editorial review in accordance with the editorial policy established by the FBI Laboratory and ASCLD. The editorial staff of the Crime Laboratory Digest reserves the right to edit all articles for style, grammar and punctuation. Comments and letters to the editor are encouraged and will be published when appropriate and as space permits. These should be forwarded to:

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ON THE COVER

The cover, prepared by the Special Projects Section of the FBI Laboratory illustrates A) zinc profile of a single strand of hair; B) cross-sectional view of X-ray spectrometer; and C) mercury profile of a single strand of hair.

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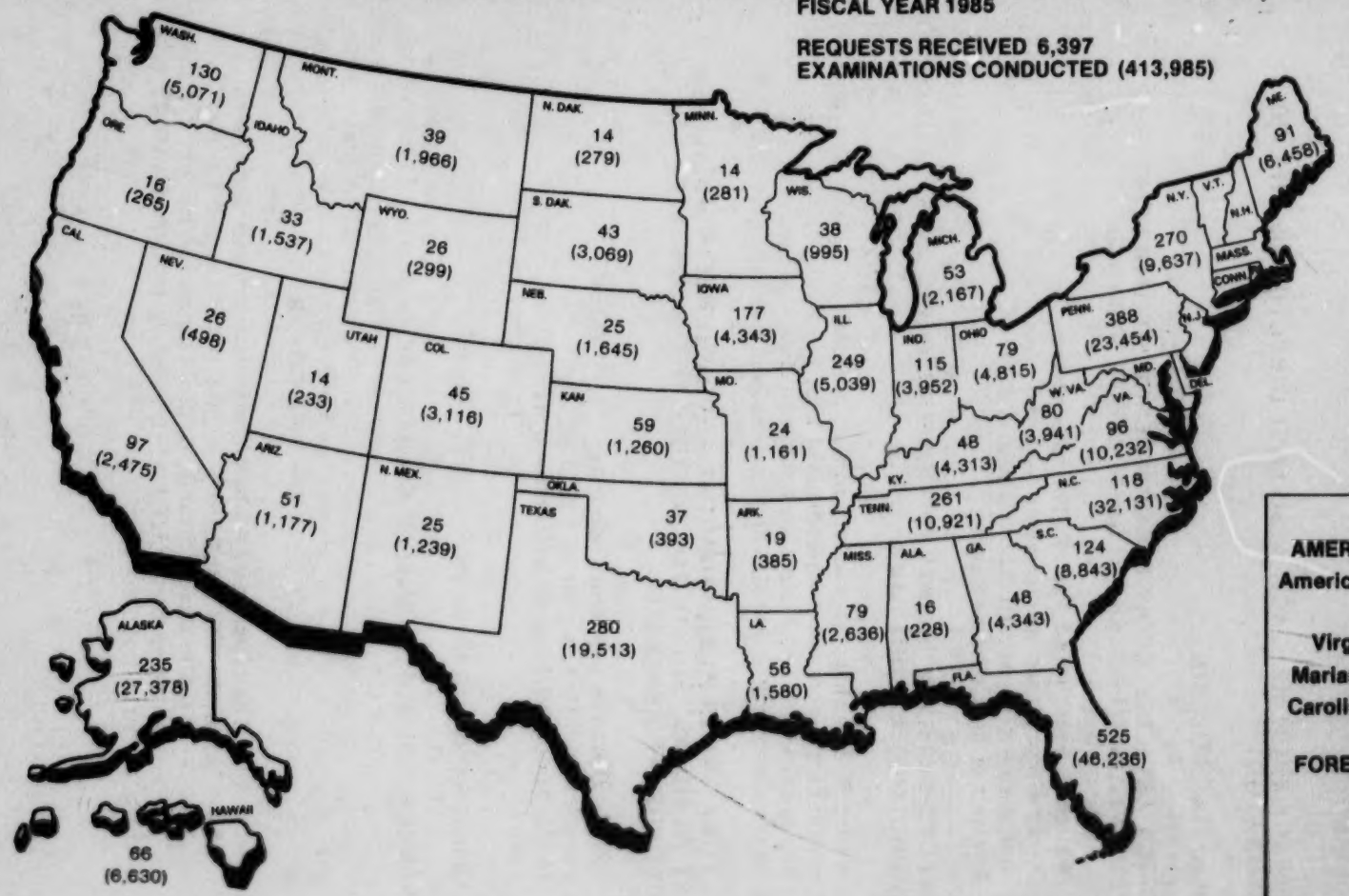
FBI LABORATORY

ASSISTANCE TO NON-FEDERAL LAW ENFORCEMENT AGENCIES

FISCAL YEAR 1985

REQUESTS RECEIVED 6,397
EXAMINATIONS CONDUCTED (413,985)



VT	44	(880)
NH	71	(1,595)
MA	136	(6,007)
CT	64	(1,421)
RI	101	(5,837)
NJ	220	(16,608)
DE	178	(13,256)
MD	523	(32,823)
DC	692	(60,941)

AMERICAN POSSESSIONS		
American Samoa	1	(2)
Guam	16	(517)
Virgin Islands	108	(6,445)
Mariana Islands	1	(10)
Caroline Islands	1	(14)

FOREIGN GOVERNMENTS		
Bahamas	8	(134)
Canada	3	(1,348)
England	1	(15)

MESSAGE FROM MR. GAST, ASSISTANT DIRECTOR OF THE FBI LABORATORY

I welcome this opportunity to rekindle friendships of many years ago, and to begin new ones within the crime laboratory community. Since leaving the FBI Laboratory 9 years ago, I have had assignments in New Rochelle, New York; Portland, Oregon; Washington, D.C.; and most recently as Special Agent in Charge of the San Francisco Field Office. During the recent American Society of Crime Laboratory Directors meeting I had the opportunity to meet and confer with many laboratory directors from all over the country and I look forward to a close and fruitful working relationship.

I have received requests to provide new types of articles in the Crime Laboratory Digest, articles on topics such as management and laboratory safety. In this issue is an article on safety in the laboratory when dealing with body fluids with emphasis on acquired immunodeficiency syndrome (AIDS) and hepatitis which was written by Walter Bond from the United States Centers for Disease Control, Atlanta, Georgia. We were asked to provide some information on this topic by Mr. Douglas Lucas, Director, Centre for Forensic Sciences, Toronto, Canada.

STATISTICAL RECAP FOR FISCAL YEAR (FY) 1985

Our fiscal year ended September 30, 1985, and I wanted to provide a brief review of the examinations performed for state and local laboratories during the period beginning October 1, 1984 and ending September 30, 1985. The FBI Laboratory received 6397 requests for assistance from law enforcement agencies which consisted of 53,252 individual evidence specimens on which 413,985 separate examinations were conducted. The map on the opposite page provides the distribution of the requests and examinations throughout the United States. These numbers remain essentially unchanged from the previous year.

Over 1000 students from crime laboratories and law enforcement agencies throughout the United States attended instructional programs in 23 different specialized courses offered at the Forensic Science Research and Training Center.

In addition, two major forensic science symposia were held at the facility. In June 1985, the FBI Laboratory hosted an International Symposium on Forensic Hair Comparisons with 172 people in attendance from forensic, academic and industrial laboratories from the U. S. and nine foreign countries. In July-August 1985, the FBI Laboratory hosted an International Symposium on Questioned Documents with 134 individuals in attendance. There were representatives from industry and government laboratories from the U.S. and four foreign countries. The proceedings of both of these symposia are in the process of being printed by the U. S. Government Printing Office and an announcement of their availability will be made in the Crime Laboratory Digest in the near future.

PLANS FOR FY 86

For this year, in addition to providing the courses listed in the October 1985 issue, we have scheduled three symposia for 1986. There is a more detailed description of these symposia in the meeting announcement section on page of this issue. However, the topics are "An International Symposium on Driving Under the Influence of Alcohol and/or Drugs" scheduled for March 24-26, 1986; "An International Symposium on Digital Image Processing for Forensic Applications" scheduled for June 11-13, 1986; and "An International Symposium on Forensic Immunology" scheduled for June 23-26, 1986. All three of these symposia will be held at the Forensic Science Research and Training Center, FBI Academy, Quantico, Virginia.

I look forward to working with you next year and seek your input on future symposia topics, future articles and other types of information we can share with you that could appear in this publication.

ROBERT S. GAST II

The article on safety in the forensic laboratory is particularly timely as the forensic community is concerned with the potential transmission of hepatitis and acquired immunodeficiency syndrome (AIDS) when working with physical evidence that contains body fluid stains. The article by Walter Bond contains the safety measures recommended by the Centers for Disease Control that laboratory workers who might encounter specimens containing hepatitis or AIDS viruses should take to prevent the transmission and acquisition of these viruses. Because of the increased probability of encountering these viruses and the potential severity of the results of this contact, the laboratory worker is well advised to educate him/herself as to the safety precautions which need to be observed, and to develop and promote laboratory practices which will minimize his/her risk from them. A recent article on this topic appears in Morbidity and Mortality Weekly Report, November 15, 1985, volume 34, pages 682-695. A recent article in The Lancet, September 28, 1985, pages 721-722, provides information on the stability of the AIDS virus at room temperature. The references listed in the "Safety in the Forensic Immunology Laboratory" article which were prepared by the Centers for Disease Control can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402.

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We are updating our current mailing list for the Crime Laboratory Digest and ask you to complete the form on page 33 and return it to us.

ANNOUNCEMENT OF SYMPOSIUM PROCEEDING AVAILABILITY

The "Proceedings of a Forensic Science Symposium on the Analysis of Sexual Assault Evidence" is now available for $9.50 through the U.S. Government Printing Office (GPO). The GPO stock number for this publication is 027-001-00037-8. Requests for this publication should be directed to:

Superintendent of Documents
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CENTRAL RESEARCH ESTABLISHMENT REPORTS

The Central Research Establishment (CRE), Home Office Forensic Science Service, Aldermaston, Reading, England, has provided the FBI Laboratory with copies of CRE Reports on completed research projects. By mutual agreement between the FBI and CRE, these reports are available to all duly authorized law enforcement organizations in the United States. To obtain these reports, send a request from your crime laboratory director to:

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The following CRE Reports are now available:

A Device for Automatic Match Temperature Detection During Refractive Index Determinations: An Assessment, J. Locke, M. Underhill, C. A. Hayes, D. Coolledge, J. A. Zoro and C. R. Howden, CRE Report #531.

The Comparison of Wall-Jet and Thin-Layer Flow-Cells, B. Law, R. Gill, R. W. Abbott and A. C. Moffat, CRE Report #536.

High-performance Liquid Chromatography Systems for the Separation of Benzodiazepines, R. Gill, B. Law and J. P. Gibbs, CRE Report #575.

Diatoms and Drowning. I. The Extraction of Diatoms from Tissue, A. J. Peabody and R. M. Burgess, CRE Report #576.

Diatoms and Drowning. II. Diatoms in the Organs of Non-drowned Subjects, A. J. Peabody and R. M. Burgess, CRE Report #577.

Diatoms and Drowning. III. Diatoms in the Organs of Drowned Subjects, A. J. Peabody and R. M. Burgess, CRE Report #578.

A Reference Collection of Infra-red Spectra of Precursor Chemicals, M. Japp, A. C. Patel and R. G. L. Osborne, CRE Report #580.

A Study of the Particles Generated When Toughened Windscreens Disintegrate, J. Locke, H. O. Badmus and A. C. Perryman, CRE Report #581.

Lewis Typing of Body Fluids by ELISA, B. G. Lang, CRE Report #582

Evaluation of a Microwave Oven for Heating Fire Debris, J. Wheeldon and J. A. Zoro, CRE Report #583.

Report on the 11th International Congress of the Society for Forensic Haemogenetics, D. J. Werrett and S. M. Fletcher, CRE #584.

REVIEW ARTICLE

X-RAY FLUORESCENCE: WITH SPECIAL APPLICATION TO SCANNING SINGLE HAIR STRANDS

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The energy dispersive X-ray fluorescence (EDXRF) method of examining physical evidence is useful to the forensic scientist for a number of reasons. In many situations samples require little preparation other than mounting them in the holder of the instrument, and quantitative elemental analyses can be made on very small samples. The method is non-destructive of the sample, a feature which is important for forensic investigations, as the same identical samples may be analyzed by more than one laboratory and may also be preserved as evidence.

X-ray fluorescence (XRF) instruments are manufactured by a number of companies, and lists of these may be found in the various guides to scientific instrumentation such as that published annually by the American Association for the Advancement of Science. The basic physical principles underlying all XRF instruments are the same, but the available instruments offer somewhat different sensitivities, sample handling attachments, and computer software for analysis and presentation of the data. Most commercial instruments are designed for general use with samples such as solids, liquids, or powders mounted on thin films which offer an appreciable area for exposure to the primary X-ray beam.

We would like to present here the basic principles of EDXRF spectrometry, and in addition describe in some detail a unique instrument which was expressly designed and built to automatically measure the concentrations of a number of elements in 1 mm segments at predetermined intervals along a single hair strand. The design was in response to a need to measure the maximum levels of Hg in the hairs of a number of women who had been exposed to methylmercury over short time intervals. The hair, if sufficiently long, preserves a record of the body level of Hg. No commercially available instrument had the required sensitivity and sample handling capability to determine the profile of an element such as Hg in a single strand of hair, and one of the authors (French) initiated the design while on sabbatical at Lawrence Berkeley Laboratory (Berkeley, CA).

Because hair is frequently available for use in forensic investigations, it is our opinion that the type of detail available in the profile of several elements along a hair should provide useful information to complement other available methods of examining hair.

ORIGIN OF SPECTRA

In XRF spectrometry the various elements in a sample are caused to emit characteristic X-rays by bombarding the sample with some type of radiation which is capable of completely ejecting inner K shell or L shell electrons. When the vacancies created are filled by electrons from higher energy shells, characteristic X-rays are emitted, and these can be used for both qualitative and quantitative analysis of the sample. These processes are illustrated in Figure 1. In most laboratory and clinical applications, X-ray tubes provide the most practical and convenient source for sample excitation.

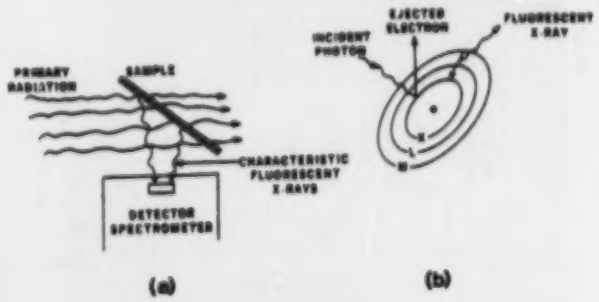

FIGURE 1. Origin of X-ray fluorescence. (A) Physical arrangement; and (B) Atomic process.

It was the development of the lithium drifted silicon detector in the mid-1960s that made possible practical energy dispersive spectrometers. A Si(Li) detector is mounted in a vacuum cryostat and cooled to liquid nitrogen temperatures along with the input FET of the preamplifier. Such a detector responds with high efficiency to X-rays below approximately 30 keV, and can have a resolution of 160 eV (FWHM @ 5.9 keV) or less. It is this excellent resolution that permits the X-rays from adjacent elements in the periodic table to be resolved.

The output of the detector preamplifier is coupled to a linear amplifier and a pulse height analyzer/computer. The output of the pulse height analyzer provides a spectrum of the number of events as a function of energy such as that shown in Figure 2.

The Rayleigh scatter, or coherent peak located at energy channel 530 in Figure 2, is due to characteristic X-rays from the target of the X-ray tube that are scattered off the sample. In addition, Compton events in the sample cause the broadened Compton or incoherent peak just to the left at energy channel 500. Below these peaks will be those due to the fluorescent X-rays from the sample, and each of these is labeled with the elemental symbol.

INSTRUMENTATION

Most instruments are oriented towards the analysis of large area (1 cm^2 or greater) homogeneous samples. The instrument described here is an automatic scanning energy dispersive spectrometer designed to analyze small areas of approximately 1 mm^2 with accuracy. As a typical hair has a mass per unit length of approximately 4 - 10 ug/mm, determination of a few parts per million (ppm) in such a small sample requires sensitivities in the picogram range for the elements of interest. This high sensitivity is achieved by using a small area collimator and very closely coupled geometry as shown in Figure 3.

The X-ray anode is made of Mo, and the excitation X-rays are primarily the 17 keV Kα photons from Mo. A Mo filter is also used between the anode and the sample to reduce the number of primary X-rays below 17 keV as these would otherwise contribute substantially to the background.

Four different computer selectable collimators were provided for in the design, but in practice two were found to be adequate for routine use. The smaller has an aperature of 1.2 mm and the larger, 2.3 mm. The automatic sample changer is in

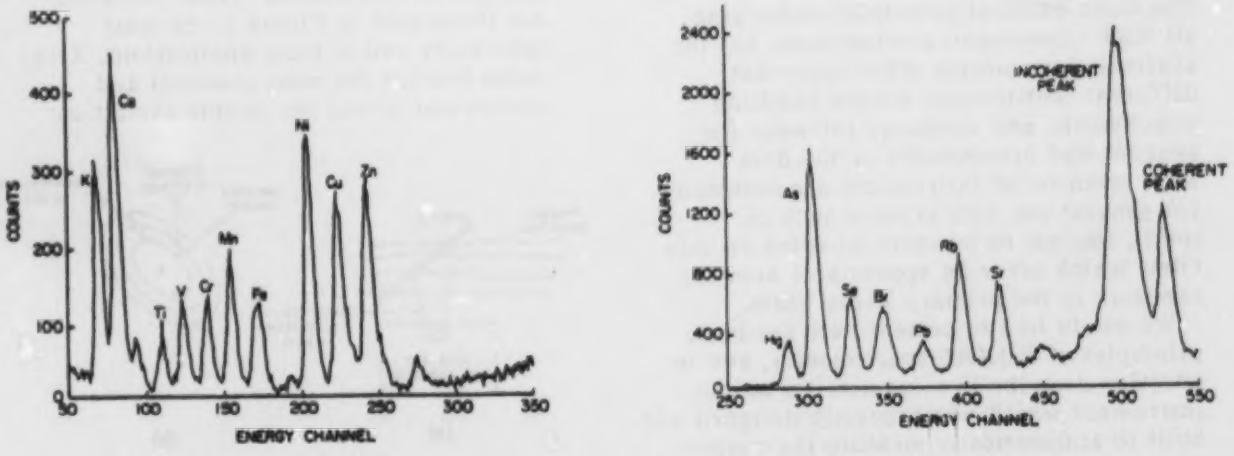

FIGURE 2. Energy dispersive spectra of a strand of hair. Left, lower energy region; right, higher energy region. Note the difference of vertical scales.

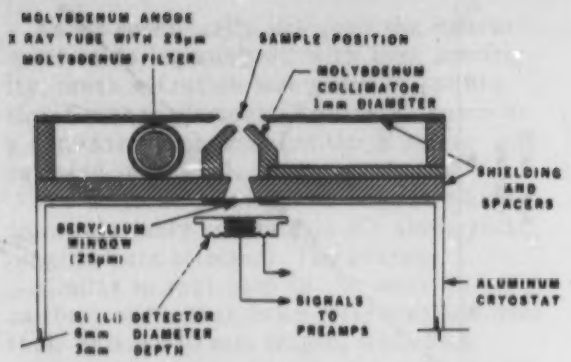

FIGURE 3. Cross-sectional view of X-ray spectrometer.

the form of a stack of 16 sample trays which will accommodate 2.00 in. (5.08 cm) wide by .125 in. (0.3175 cm) thick Lucite mounting frames. These are made in three lengths of 3, 6 and 12 in. (7.62, 15.24 and 30.48 cm), respectively. A hair to be analyzed is mounted by stretching it between two small holes accurately centered on the frame ends so the hair will accurately track over the detector collimator. The hair is held in place with Scotch Magic Mending Tape [R], and any excess is taped down to the top of the frame. If handled with care, a hair may be mounted, analyzed, unmounted and remounted with no observable change in the analytical results. Figure 4 shows a picture of the hair analyzer with the sample changer stack located in the center of the picture. Figure 5 shows a close-up view of a 12 in. (30.48 cm) mounting frame with a hair mounted.

This system permits analysis within approximately 10 mm from the end. If analysis is desired closer to an end, the hair may be cemented to another fiber such as fine thread with a cyanoacrylate adhesive. This permits analysis to within 2 mm of the end. Special 3 in. (7.62 cm) frames have been devised to hold a hair from one end only so as to get analyses of the bulb end if that is desired.

In the analysis mode, a frame is advanced by a stepping mode under computer control and an analysis is made at the first point desired. Then, as this spectrum is being processed, the frame is advanced to the selected increment and a new spectrum taken.

Details of the hardware and the various options in the operating software have been described previously (Toribara et al. 1982) and will not be covered here, but a few details concerning quantitative calculations using the energy dispersive technique are in order. The raw spectrum is first stored in computer memory. Then, a background which has been derived from a real hair with the fluorescent elemental peaks removed, is subtracted in three steps, each of which covers a particular region of the energy spectrum. The appropriate background region is first scaled by comparison with carefully selected points on the hair spectrum where no peak occurs.

The overlapping nature of the Kα and Kβ X-ray energies for the various elements,

FIGURE 4. External view of entire instrument.

FIGURE 5. Sample mounting frame.

and the even more difficult overlap between the K series for some elements and the L series for heavier elements makes it necessary to accurately "strip" all X-ray peaks due to a given element from the net elemental spectrum as that element's concentration is determined. For example, a $K\alpha_1$ peak at 10.543 keV is not resolved by the spectrometer from the Pb $L\alpha_1$ at 10.549 keV. Only a very careful spectral stripping routine will provide a determination of As in the presence of Pb.

The quantitative elemental amounts in picogram/millimeter are determined in an iterative manner with the highest peak in a series of elements being subtracted first. A standard peak shape, stored in memory, is used to subtract all peaks due to that element to reduce inter-element effects. Also stored in memory are the calibration constants appropriate to each element. The area under a peak is related to the quantitative amount, but each element is excited with different efficiency.

In order to determine ppm values for each element, it is necessary to determine the mass/millimeter value at each point where an analysis is to be made. The integrated count under the incoherent peak is directly related to the total number of electrons exposed to the X-ray beam, which in turn is related to the mass of the sample seen by the beam, principally the hair itself. The area of this incoherent peak has been correlated with an electrobalance weighing of the same portion of a number of hairs. This correlation is shown in Figure 6. The mass at any given point calculated per millimeter of hair is combined with the elemental concentrations to give ppm values for each element.

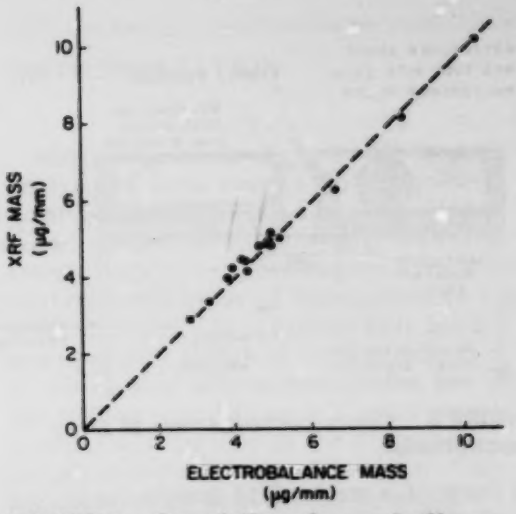

FIGURE 6. Correlation of mass by X-ray fluorescence versus electrobalance.

CALIBRATION OF ELEMENTAL ANALYSES

It is impossible to construct an XRF instrument having such high sensitivity with predetermined, absolute calibrations for elemental analyses, and techniques must be devised to provide the necessary calibration data. It is first useful to determine the relative sensitivities for the different elements. For this purpose, thin samples can be prepared on mylar film which have known stoichiometric ratios. This curve can be prepared as a function of the atomic number of the elements, and is a smooth curve as shown in Figure 7. The sensitivities are different for the K and L lines, and so the instrument must be calibrated against some other reliable techniques for at least one element in the K series and one element in the L series.

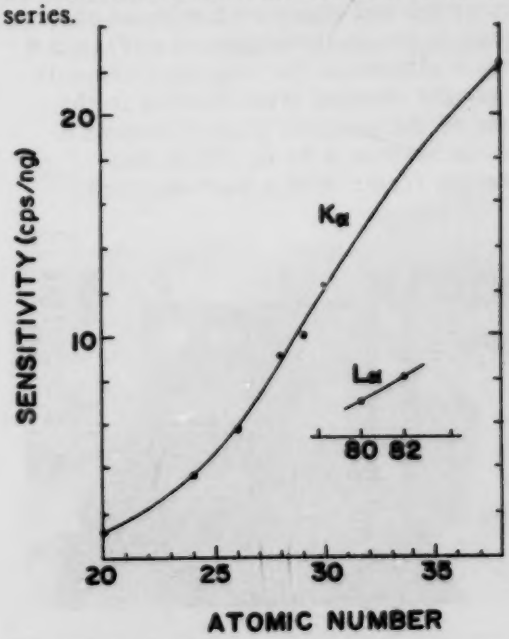

FIGURE 7. Relative sensitivity as a function of atomic number.

As we specifically designed the instrument to do Hg analyses with high sensitivity, much attention was given to calibration for that element. Zinc was chosen as a convenient element for the K series calibrations.

For calibration purposes strands which were relatively constant in Zn along their lengths were selected. The process is similar to that used in the mass calibration in that hairs were scanned over their entire 270 mm length, with data points taken every 5 mm. A counting time of 300 live time seconds was adequate to give counting errors of approximately ± 2 percent. This same length was then cut out, weighed, dissolved in concentrated nitric acid and diluted to volume. The Zn content was then determined by using a Varian AA-5 Atomic Absorption Spectrometer. Figure 8 shows comparison of the XRF-measurements to the Zn content by atomic absorption. It was useful to artificially spike hairs with Zn to provide a linear calibration range.

Standardizations for Hg were carried out in a similar manner to those for Zn with the exception that the hairs chosen contained no naturally acquired Hg. Different amounts of Hg were deposited on the hairs by soaking them for different time periods in methylmercurychloride. After drying at room temperature, the hairs were scanned by XRF and sections cut out to permit analysis by cold-vapor atomic absorption. Figure 9 shows the results of the Hg by XRF versus atomic absorption data. The slope of the calibration line is 0.97 and the Y axis intercept is approximately a +8.9 ppm offset. Using these data small changes were made in the background subtraction routine and sensitivity constants to bring the two instruments into even closer agreement.

RESULTS AND DISCUSSION

Prior to the development of this instrument, it was necessary to cut bundles of hairs in 1 cm lengths to be analyzed by the cold-vapor atomic absorption technique in order to provide a profile of the Hg content of hair. Figure 10 shows a comparison of the old bundle method as compared to the single strand method for the Hg content in the hair of an Eskimo fish eater. In contemporary times, the highest concentration of Hg is found in the hair of those whose diet consists heavily of fish. It may be seen that much more detail is shown in the single hair profile.

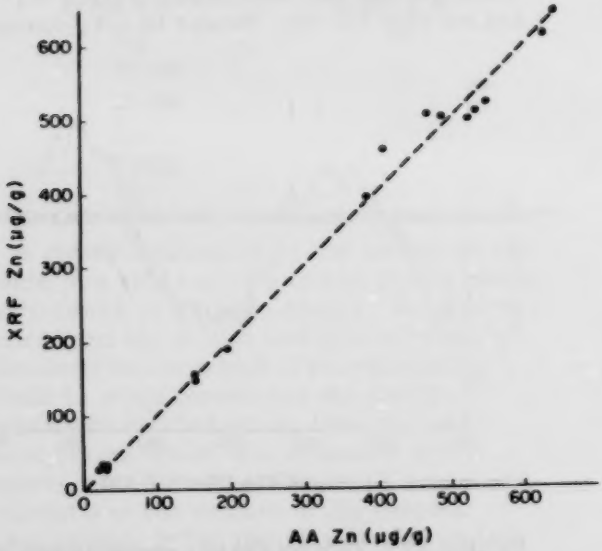

FIGURE 8. Calibration of low energy region of spectra using zinc.

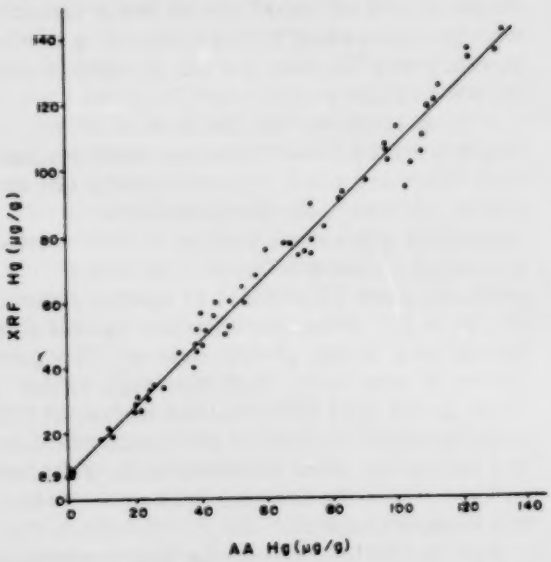

FIGURE 9. Calibration of high energy region of spectra using mercury.

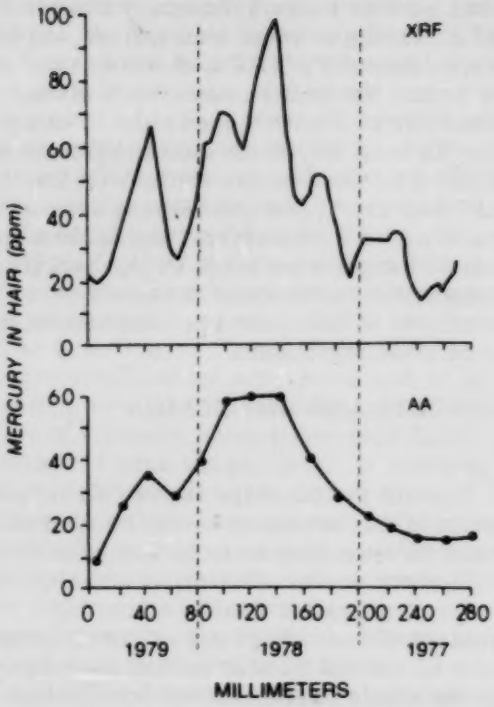

FIGURE 10. Comparison between old bundle method versus single strand for profile development.

The fine details of the Hg profile of a single strand of hair from an Iraqi woman who had consumed bread containing methylmercury over a short period of time is shown in Figure 11.

Figure 12 shows the Zn profile of a single strand of hair from an Iraqi woman, note there are peaks approximately 120 mm apart. We attribute this pattern as indicating a seasonal change in diet which is related to the availability of crops with a higher Zn content at certain times of the year. From the distance between the peaks, an average growth rate of 1 cm per month is obtained. With that figure, the peak in the Hg profile which occurs at 270 mm from the root end would indicate that the maximum level occurred some 27 months prior to the time the hair was taken from the woman's scalp.

For medical purposes, the hair concentrations are only useful if they can be directly related to the concentrations

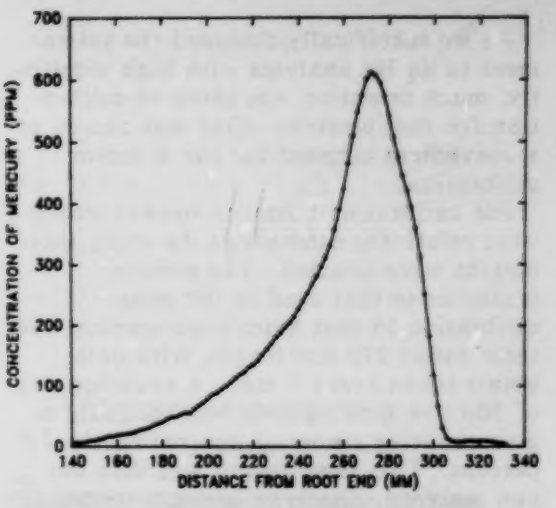

FIGURE 11. Mercury profile of a single strand of an Iraqi woman's hair.

existing in the blood at the time the hair was formed. The elements that can be determined for a single strand of hair, in addition to the mass/length, are Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Br, Rb, Sr, Hg and Pb. For most of these elements, the hair levels can be influenced by exposure to water with certain elements present: shampoos, airborne particulates and elements in the perspiration. At present, the relationship between the blood concentration and hair concentration is known only for Hg. Except in very unusual

FIGURE 12. Zinc profile of a single strand of an Iraqi woman's hair.

circumstances, the Hg concentration found in hair may be related to the blood level at the time the hair was formed because that element is not usually found in the environment, and it cannot be removed from the hair without destroying the hair.

Table 1 shows some of the ions removed by washing (Kopito and Swachman 1975; Salmela et al. 1981) and added from a solution similar in composition to sweat (Bate and Dyer 1965). Unless precise information is known concerning the conditions under which the hair has been exposed, no reliable correlation between the elemental composition of the hair and the health of the individual can be made.

Table 1. External Removal or Addition of Ions

Ions Removed by Washing	
Br	K
Ca	Mg
Cd	Mn
Cl	Na
Cu	Zn
Fe	

Ions Added From Sweat Solution	
At pH 5.5	At pH 3.5
Ag	Br
Cr (3)	Cl
Cr (4)	I
Cu	Se (2)
Fe (3)	
Zn	

A recent application of the technique was made in a study of two frozen bodies which were found in Barrow, Alaska. We obtained hairs from the bodies and selected some of the elements for which some conclusions could be made concerning the dietary conditions existing at the time the bodies were buried which was estimated to be approximately 400 years ago. Of particular interest was the amount of Hg present. This element is found today largely in fish such as the swordfish. Figure 13 shows a comparison of the Hg profiles of the Barrow hairs with those of two modern fish-eaters:

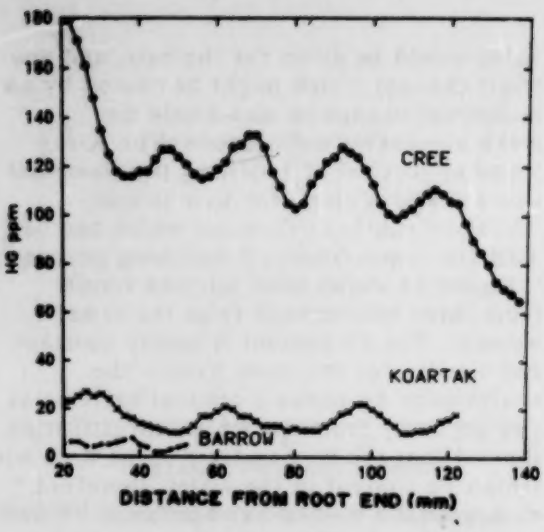

FIGURE 13. Mercury profiles of two modern Northern fish eaters compared with that of a frozen body of 400 years ago.

a Cree Indian who consumed large amounts of fish caught in an inland lake in Northwestern Quebec known to have been contaminated by industrial wastes, and a Koartak Indian from Northeastern Quebec whose diet of fish from ocean waters would be similar to that of the Barrow natives. The Hg levels in the Barrow hair are much lower than that of the present day fish-eater and would indicate that portion of the ocean today is more heavily contaminated with Hg than it was 400 years ago. It does not give any clues as to whether the increase is from natural sources, man-made, or some combination of the two, however.

For forensic purposes the possibility of determining two hairs to be from different individuals may be quite certain, but the establishment of identity must be undertaken with caution. For the case where differences can be shown by the presence of an element in one sample and its absence in another, it would be a simple matter by any type of analytical technique to establish a difference. Because the usual chemical methods or the atomic absorption instrumental methods can measure nanogram quantities, either an entire hair strand or several strands must be taken to supply the amounts necessary for measurements. Thus, only an average

value would be given for the hair, and any small changes which might be caused by an occasional change in diet would not make observable differences. The X-ray scanning method of profiling the elemental concentrations along the hair strand will show subtle differences which can be used for comparison and matching purposes.

Figure 14 shows some selected results from three hair strands from the same woman. The Zn content is nearly constant and similar for the three hairs. The analysis for Fe shows a gradual increase as you get away from the scalp. Investigation showed that the woman lived in an area with a high Fe content in the water; therefore, each time she washed her hair some Fe was added. Note in Figure 14 the curve extrapolates back to what would normally be expected.

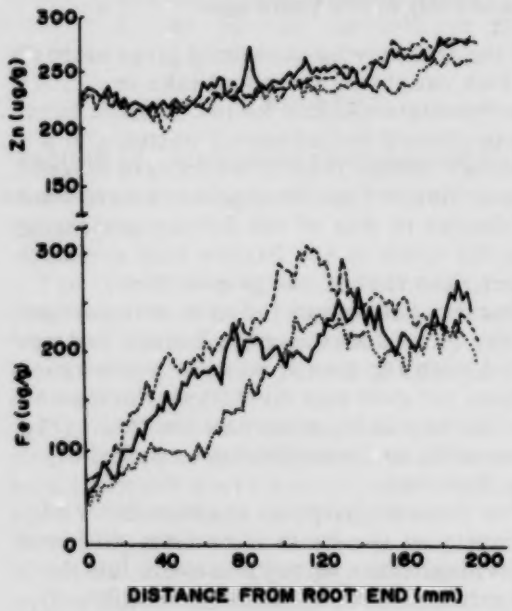

FIGURE 14. Zinc and iron profiles of three strands from the same woman.

In a recent rape-murder case we were contacted by the Public Defender's office which had heard of the hair analysis instrument. It was a desperation effort on their part, hoping the instrument would show that a hair found on the victim's body was different from that of the suspect. Three samples were submitted to us as follows: (1) taken from the victim's body, (2) taken from the suspect immediately after the crime and (3) taken from the suspect 4 months later.

The trial was in progress when we received the samples. The evidence at the time was that the hairs were all from a Negro male. The other evidence was overwhelming against the defendant, and a guilty verdict was returned about the time we completed our study. It will be obvious that the defense would not have wanted to use the evidence in any case.

We pointed out earlier that this instrument can show positively that two hairs are different, but similarities would not necessarily be absolute evidence that two hairs were identical. We selected two elements, Zn and Cu, for use in our analysis as shown in Table 2. It can be seen that the average concentrations of both elements in the hair taken from the victim and from the suspect immediately after the crime are essentially identical. The sample taken 4 months later shows marked differences in the content of the two elements.

Since the hair content is a reflection of dietary and other external factors, similarities may occur in others with similar diets and environmental exposure. In the present case we noted the Zn level

Table 2. Analysis of Suspect's Hair by X-Ray Fluorescence

	Zn (ppm)*	Cu (ppm)*
Victim	97.0	28.8
	95.7	28.8
Suspect (sample obtained immediately after the crime)	98.8	25.3
	99.3	24.7
Suspect (sample obtained 4 months after the crime)	70.7	48.1
	71.2	47.7

* Parts per million

was approximately half that which would be expected in a person with the diet available to one in urban surroundings. One cause for low Zn is alcoholism, and the Public Defender stated the suspect was both an alcoholic and a drug addict. The suspect also had been in prison since the crime, and a considerable change in diet was evident in the levels of the two elements.

This last fact indicates the importance of obtaining hair samples as soon as possible in an investigation. In hairs that are sufficiently long, the profile can pinpoint times when dietary changes occur. Figure 15 shows the Hg profile of a hair taken 7 months after a woman had arrived in the United States from Japan. the Japanese have a high fish diet which is the source of most of the Hg intake. The drop in the Hg content of the hair toward the low level found in most of the non-fish eaters starts near 70 mm from the root end which corresponds to the time she arrived in the United States. Similar drops in the Hg content in the hair of other Japanese have been found after they have been in the United States for extended periods.

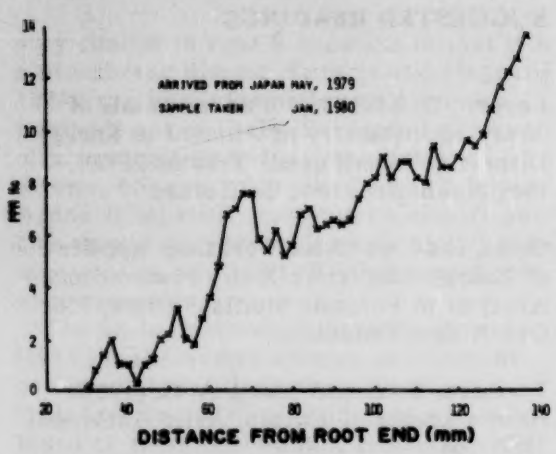

FIGURE 15. Mercury profile of a Japanese woman who had changed diets.

SUMMARY

X-ray fluorescence provides a very sensitive method for the non-destructive elemental analysis of a variety of samples. The non-destructive features should be useful for forensic purposes because identical samples may be analyzed by several laboratories possessing similar instruments. In most cases, samples need only be mounted in the holders so that no time is needed for pretreatment.

We have described an instrument which was expressly built to sequentially measure 16 elements simultaneously in 1 mm segments of hair giving the profile of the concentrations along the hair. For some elements the concentration is related to the blood level existing at the time the hair was formed, and the profile provides a history of the blood level of those elements. In other cases profiles may show unique environmental influences. These profiles can show positive dissimilarities between two hairs, or strong similarities. Such information should be useful in the investigation of forensic problems.

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FEATURE ARTICLE

SAFETY IN THE FORENSIC IMMUNOLOGY LABORATORY

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This paper addresses the safety concerns of personnel such as those working in a forensic science laboratory where it is common to encounter on a daily basis potentially hazardous biologic material in either moist or dried states, for example, blood, semen, saliva or items stained by these fluids. Of the bloodborne diseases, two having the highest levels of concern today are viral hepatitis B and acquired immunodeficiency syndrome (AIDS). Since hepatitis B virus (HBV), like "AIDS virus," is a bloodborne virus and is present in much higher titer and is also more stable to physical or chemical stresses than "AIDS virus," it serves as a "worst case" scenario with respect to recommendations for preventing transmission of either infectious agent. Current safety recommendations for "AIDS virus" are virtually identical to those for HBV (Centers for Disease Control 1982, 1985). The majority of this paper is excerpted from a 1982 publication I authored pertaining to general as well as hepatitis B safety in a clinical laboratory (Bond 1982). The reader is also encouraged to make extensive use of the referenced material for more detailed information.

It is well recognized that viral hepatitis type B is an occupational risk among personnel working in health care fields, especially those who are employed in clinical and forensic laboratories. Hepatitis B is the most commonly reported laboratory-acquired infection, and laboratorians who frequently handle blood or blood-contaminated bodily products are at higher risk than the general population for acquiring infection (Maynard 1978a; Pike 1979; Levy et al. 1977). Although non A/non B hepatitis has not been reported as a major laboratory-acquired infection, its epidemiology appears to be very similar to type B hepatitis in that it is a bloodborne disease (Francis and Maynard 1979); specific information on high-risk groups is not available because of the lack of a serologic test. It is reasonable to assume, however, that like hepatitis B, non A/non B hepatitis constitutes a significant risk among workers in forensic and clinical laboratories, and the following text should apply accordingly.

The basic reservoir of hepatitis B virus (HBV) is the human chronic or transient carrier of hepatitis B surface antigen (HBsAg). In addition to its presence in the blood of these individuals, HBsAg has also been detected in other body fluids, excretions and secretions. These include urine, feces, saliva, nasopharyngeal washings, breast milk, bile, semen, synovial fluid, sweat, tears, peritoneal fluid and cerebrospinal fluid. Since these substances contain detectable HBsAg, it has been hypothesized that they may be infectious. There is general agreement, however, that a fecal-oral route of hepatitis B transmission does not exist (Favero et al. 1979; Maynard 1978b). Transmission by these other fluids may be possible; however, blood is acknowledged to be the most commonly effective vehicle of HBV transmission.

The efficiency of the various mechanisms of hepatitis B transmission within a laboratory environment is related significantly, if not solely, to the extraordinary amounts of circulating HBV in the blood of infected individuals. Blood diluted to such an extent that HBV is present in relatively small inocula or on laboratory environmental surfaces in the absence of visible or even chemically detectable blood can still be infectious. It has been shown, for example, that human serum containing both HBsAg and hepatitis B e antigen (HBeAg-a serologic marker closely associated with infectivity) can be diluted to 10^{-8} and still produce hepatitis B infection when injected into susceptible chimpanzees (Shikata et al. 1977). It has also been shown that HBV in plasma will survive and cause infection after being dried and then stored at 25°C and 42 percent relative humidity for 1 week (Bond et al. 1981).

ROUTES AND MECHANISMS OF HEPATITIS TRANSMISSION IN LABORATORIES

The following are modes of hepatitis B transmission that can occur in a variety of epidemiologic settings including laboratories and are listed in the probable order of efficiency of disease transmission.

Direct Contact

1. Direct percutaneous inoculation of contaminated serum or plasma such as occurs by accidental sticks or cuts by needles or other objects.

2. Percutaneous transfer of infective serum or plasma in the absence of overt puncture, such as contamination of minute scratches, abrasions, burns, or any other lesions.

3. Contamination of mucosal surfaces by infective serum or plasma or infective secretions or excretions such as occurs with accidents associated with mouth pipetting, label licking, splashes or splatterings or other means of skin-to--mouth or skin-to-eye contact. In a recent study (Bond et al. 1982) we showed that a chimpanzee was infected 63 days after inoculation of its corneal surfaces with 50 ul of plasma known to contain HBV.

Indirect contact. Hepatitis B transmission can occur by indirect means via common environmental surfaces in a laboratory such as test tubes, laboratory benches, laboratory accessories and other surfaces contaminated with infectious blood, serum, secretions, or excretions which can be transferred to the skin or mucous membranes. The probability of disease transmission with a single event in this category may be remote, but frequency of such events makes this mechanism of transmission potentially an efficient one over a long period of time. Activities in laboratories such as nail biting, smoking, eating and a variety of hand-to-nose, -mouth and -eye actions, may contribute to indirect transmission.

Airborne transmission. Although hepatitis B transmission by means of the airborne route has been hypothesized, it has never been documented. We have performed two studies, the results of which show true airborne transmission of hepatitis B from infectious blood or saliva is not likely. In one study (Petersen et al. 1976), a filter-rinse technique capable of detecting low levels of aerosolized airborne HBsAg was devised, evaluated and used in a hemodialysis center serving a patient population with a high prevalence of HBsAg seropositivity and one in which conditions favored the production of aerosols; HBsAg was not detected in any of 60 air samples collected. In the second study (Petersen et al. 1979), air samples were collected in a dental operatory at an institution for the mentally retarded where residents had a high incidence of HBsAg seropositivity. Although gingival swab samples from nearly all of patients showed the presence of HBsAg, air samples collected during procedures of scaling, extraction, high-speed drilling and other procedures favoring aerosol production were likewise uniformly negative for HBsAg. However, in a separate study concentrating on HBsAg contamination of environmental surfaces in and around hemodialysis centers, 15 percent of frequently touched surfaces were shown to be contaminated when a swab/rinse sampling technique (Bond et al. 1977) was used. Consequently, true aerosols, that is, particles less than 100 um in diameter, appear to be less significant hazards than contaminated surfaces. It should be pointed out, however, that events such as splashing, centrifuge accidents, or removal of rubber stoppers from tubes can account for disease transmission by means of large droplet transfer into the mouth, eyes, minor cuts or scratches, or onto abraded skin. This is not true airborne (aerosol) transmission, but rather transmission by direct droplet contact.

SPECIFIC PRECAUTIONS FOR PREVENTING LABORATORY-ACQUIRED VIRAL HEPATITIS

The primary strategy that should be used in preventing laboratory-acquired viral hepatitis B is the consistent practice of

blood precautions. This is true not only in laboratories where blood, serum and other specimens are processed from patients who are known to be infected with hepatitis but in all clinical laboratories involved in the biochemical, hematologic and microbiologic assay of blood and blood products. The prevalence of HBsAg in sera of patients whose blood is being assayed varies with the population being served by the laboratory. However, one can assume that this prevalence would be approximately 1 percent in the total population, while in specific high-risk groups such as hemodialysis patients, parenteral drug abusers, or male homosexuals the HBSAg carrier rate may be significantly higher. Consequently, laboratories that process hundreds to thousands of blood samples per day will, without doubt, handle a blood specimen that contains HBV but is not labeled as such. It is common practice to prominently identify specimens and specimen containers with a "hepatitis" label when dealing with known hepatitis patients. Unfortunately, two sets of blood precautions are sometimes practiced in the laboratory: very careful ones with those tubes labeled "hepatitis" and fairly lax ones with unlabeled specimens from other patients. It is emphasized that blood precautions should be employed at all times in the laboratory environment.

The following guidelines are designed and presented specifically for the prevention of laboratory-acquired viral hepatitis B but could be considered applicable in routine laboratory practices to limit the acquisition of other infectious diseases as well.

Safety officer. The responsibility for laboratory safety resides ultimately with the director of the laboratory; however, from an operational standpoint a safety officer who is familiar with laboratory practices and biohazards should be appointed from among the laboratory staff. The laboratory officer should be responsible for giving advice and consultation to the laboratory staff in matters of biohazards, instructing new members in safety procedures, procuring protective equipment and supplies, developing and maintaining a laboratory accident reporting system, periodically reviewing and updating safety procedures and monitoring serologic surveillance data for the laboratory staff if such data are collected.

Reporting of accidents. Accidents such as cuts, needle sticks, and skin abrasions with instruments possibly contaminated with blood, and soiling of broken skin, or contamination of the eyes or mouth must be reported promptly to the safety officer who should maintain records and make sure that proper medical consultation and treatment, if necessary, are available. Spills of high-risk specimens such as documented or suspected HBsAg-positive blood, even if not associated with personnel contamination, should also be reported to the safety officer.

Handwashing. Frequent handwashing is an important safety precaution that should be practiced after contact with specimens and laboratory procedures, especially those associated with blood or blood products. Hands should always be washed before eating, drinking, or smoking and after completing analytical work. Frequent handwashing should be performed even if gloves are used for particular procedures. Handwashing facilities should be conveniently located for frequent use, and a handwashing product that is widely acceptable to personnel is desirable. Liquid or granule soaps are preferable to bar soaps.

Gloves. All laboratorians who have direct or indirect contact with blood or articles contaminated with blood should wear gloves. It should be realized, however, that gloves can become contaminated in use and should not contact surfaces such as telephones, door knobs, marking pens, laboratory equipment, etc., frequently touched by other ungloved laboratorians. Disposable single-use, nonsterile gloves are preferred because they can be changed frequently.

Protective clothing. A gown with a closed front, a coat with an overlapping front, or a disposable plastic apron should be worn in any laboratory area. Disposable gloves should be used when opening or processing specimens. Gowns, apron, and gloves must be removed, and hands should be washed before a staff member leaves the laboratory for any purpose. Disposable gloves and

aprons should be worn only once and in an impervious bag for safe disposal. Gowns and coats should be placed in a laundry bag at the end of each appropriate period of work. If the gown or coat is accidentally contaminated, it should be discarded in the laundry bag at once and a fresh one obtained. A face shield or protective eyeglasses and mask should be worn when it is anticipated that there is a potential for blood and other types of specimens being spattered into the laboratorian's face (Bond et al. 1982).

Personal hygiene. Smoking, eating and drinking in the laboratory should be prohibited. Care should be taken not to put fingers, pencils, or other objects into the mouth, specimen tube labels must not be licked, and hands should be washed after every procedure in which they may have become contaminated.

Pipetting. Mouth pipetting should be prohibited; automatic pipettes with disposable plastic tips are recommended. If disposable pipette tips are used, they should be employed as such and discarded after pipetting each specimen, for example, they should not be rinsed several times in water between each specimen. Other pipettes should be used with rubber bulbs or an automatic suction device, and fluids should never be drawn up to the top of pipette. Contaminated pipettes must not be placed on the laboratory bench; they should be placed gently in a flat discard pan and later completely submerged in disinfectant. Any rubber bulb that may have become contaminated internally during use should be placed into disinfectant and subsequently discarded.

Receipt of specimens. Incoming blood specimens should be received in a designated area of the laboratory and examined closely to be sure they have been properly packed. Soiled or leaking containers should be brought to the attention of the safety officer to decide whether or not they should be autoclaved and discarded without being unpacked. Disposable gloves should be worn during the unpacking procedure.

Labeling, processing and storage of blood tubes. Blood, serum and biologic specimens from patients who are known to be infected with hepatitis or for whom hepatitis B or serum enzyme tests are being performed should be identified with special labels marked "hepatitis". It should be re-emphasized, however, that precautions employed by laboratorians when handling these types of high-risk specimens should be no different when handling specimens that are not labeled as such. Because blood tubes may be contaminated on the outside (Centers for Disease Control 1980) as well as contain infectious blood, they must be handled and stored with care. If blood tubes must be refrigerated, they should be capped and placed in a designated refrigerator or in a designated portion of a refrigerator. Blood tubes should never be kept in a refrigerator that contains food or beverages.

Needles and syringes. Special precautions should be taken with needles and syringes which are blood contaminated. Disposable needles and syringes should be used and should then be discarded after a single use. Used needles should not be recapped; they should be placed in permanently labeled, leak and puncture-resistant containers designed for this purpose. Needle nippers should not be used and needles should not be purposely bent or broken by hand since accidental needle punctures are likely to occur during this procedure. Used syringes should be placed in a leak-resistant bag, and all containers or needles or syringes should be either incinerated or autoclaved before discarding.

Disposal of waste specimens and contaminated material. All blood and most biologic specimens from humans or from primates used in hepatitis research must be viewed as potentially infectious. Accordingly, when these materials become waste, they must be disposed of in a safe manner. Each laboratory should have special receptacles for these wastes. Preferably, the wastes should be autoclaved in the laboratory or transported in double impervious bags for terminal processing in an autoclave or approved incinerator. Where it

is not feasible to autoclave blood or other potentially infectious fluids, they may be poured down a single sink drain designated for this purpose. Gloves should be worn during the procedure and care should be taken to prevent splashing onto the walls of the sink. After a sink drain is used for fluid disposal, it should be thoroughly flushed with water (minimizing splashing) and the sink and drain should be treated with an appropriate liquid disinfectant.

Centrifuging. Specimens containing blood should be centrifuged with tubes tightly capped. If a tube breaks in the centrifuge, the bucket containing the spilled blood and broken glass should be placed gently in a pan of disinfectant; the surfaces of the centrifuge head, bowl, trunnions, and remaining buckets should be swabbed with an appropriate disinfectant; alternately, the trunnions and buckets can be autoclaved. Micro-hematocrit centrifuges and bloodbank serofuges should be cleaned daily.

Automated equipment. Automated equipment capable of performing a number of biochemical assays simultaneously are becoming commonplace in clinical laboratories. However, it is not evident that any instrument or class of instruments pose significant risks of hepatitis transmission due to external or internal design. Rather, the potential risks of hepatitis transmission are associated with procedures involving specimen handling, specimen preparation, and delivery of the specimen to the automated equipment. Gloves should be worn by operators of this equipment at all times. If blood or serum ultimately is collected in a reservoir which is not piped into the sewer system, the contents of the reservoir should be autoclaved before disposal. If this is not feasible, the contents should be poured into a designated sink drain as described previously for fluid wastes.

Care of laboratory bench tops. Each working area should be supplied with a wash bottle containing an appropriate disinfectant. The disinfectant solution should be mixed and renewed according to the direction on the manufacturer's label, and the bench surface must be cleaned and wiped with disinfectant at the beginning and end of each day or more frequently as spills or contamination occur. Since accidents and errors are most likely to happen when the laboratory work area is crowded with equipment and materials, care should be taken to keep the laboratory work area tidy. Tubes and other containers should be placed only in the appropriate rack or tray, never directly on the bench. Disposable, absorbent, plastic-backed pads can be used to protect laboratory bench tops where spattering or spills are common or anticipated.

IMMUNE PROPHYLAXIS

The Advisory Committee on Immunization Practices (ACIP) of the U.S. Public Health Service periodically publishes recommendations and strategies for use of the hepatitis B vaccine as well as immune globulins for protection against several types of viral hepatitis (Recommendation of the Public Health ACIP 1981). These recommendations are updated periodically in the Centers for Disease Control's Morbidity and Mortality Weekly Report.

The hepatitis B virus vaccine licensed for use in 1982 is currently available for both pre- and post-exposure prevention of hepatitis B. The vaccine, given in a three-dose series, is over 90 percent effective in preventing HBV infection, has minimal side effects, and is recommended for the pre-exposure prevention of hepatitis B. Laboratorians, especially those who frequently handle human or primate blood, are at high to moderate risk of hepatitis B infection and should consider receiving hepatitis B vaccine. There are no vaccines available for other hepatitis viruses.

Immune globulins (IG) are sterile solutions of antibodies prepared from large pools of human plasma, and IG (formerly referred to as "immune serum globulin," ISG, or "gamma globulin") produced in the United States since 1977 contains relatively stable amounts of antibodies against HBV and HAV. Hepatitis B immune globulin (HBIG) is prepared from plasma pre-selected for high titer of hepatitis B antibodies, and the cost

of HBIG on a per-dose basis in approximately 20 times that of IG.

Personnel who frequently handle blood should be considered as candidates for the HBV vaccine. Post-exposure prophylaxis may be warranted in the event of percutaneous or permucosal exposure to blood or body fluids known or thought to contain HBV. The final decision to provide prophylaxis must take into account 1) whether the source of the blood or fluids is known or unknown, 2) whether the HBsAg status of the blood or fluids is known or unknown, and 3) the anti-HBs or HBV vaccination status of the exposed person. If post-exposure prophylaxis is to be given, it should be done as soon as possible after exposure (no later than 7 days). The reader is referred to the complete ACIP guidclines for details (Recommendation of the Public Health ACIP 1981).

It is important to recognize, however, that after the use of a vaccine, a natural immunity to hepatitis B or any other disease for that matter should never be considered as a substitute or replacement for proper techniques (asepsis, cleaning, disinfection or sterilization) in the laboratory.

DISINFECTION, STERILIZATION AND DECONTAMINATION

Since hepatitis B virus cannot be propagated in tissue culture, comparative virucidal testing has not been performed as it has been for other types of viruses that can be conveniently cultured and tested in the laboratory. Consequently, there is little known about the precise inactivation kinetics of HBV by physical and chemical agents, and this situation has led many experts to recommend nothing less than a sterilizing treatment when dealing with contamination by this virus. Unfortunately, this type of recommendation has fostered the concept that HBV is some sort of a "super virus" in terms of its resistance to chemical and physical agents. Bond, Petersen, and Favero (1977) have pointed out that although HBV may be comparatively more resistant to a variety of physical and chemical agents than most viruses, it is unreasonable to assume that the resistance level is equivalent to that of bacterial endospores. Until additional data become available, they proposed that the resistance of the human hepatitis viruses should be considered to be greater than that of the tubercle bacillus but less than that of bacterial spores and probably closer to the former. They further pointed out that conventional sterilization treatments will inactivate HBV. With disinfection processes, however, one must rely on empirical observations. The HBV is not more resistant nor does it approach the resistance levels of bacterial spores; this is known because boiling for two minutes inactivates HBV in serum. Therefore, a physical or chemical treatment known to exhibit sporicidal activity should also be virucidal for HBV. Furthermore, because of the exhibited high stability of the HBsAg, a treatment that fully or partially inactivates the immunologic reactivity of this antigen should also inactivate HBV. This rationale and strategy are reviewed at length by Bond et al. (1977) and are beyond the scope of this article. However, they did recommend that environmental HBV contamination be dealt with using chemicals, concentrations, and contact times capable of producing at least an intermediate level of disinfectant action. Table 1 lists a number of chemical germicides which, if used correctly, can be considered effective for the inactivation of the hepatitis B virus. The liquid chemicals, as will be mentioned below, are used primarily for purposes of decontamination for spills of known HBsAg-positive blood. They are not generally recommended for routine housekeeping purposes.

Note: Since the original publication of this paper, it has been shown that the resistance level of hepatitis B virus to liquid disinfectant chemicals is not as high as once believed (Bond et al. 1983; Kobayashi et al. 1984).

In fact, even the intermediate-level disinfectants listed in Table 1 (iodophors, hypochlorite) in addition to 70 percent isopropyl or ethyl alcohol have been shown effective in killing large numbers of HBV in plasma or serum. Alcohols are still not recommended for general disinfecting purposes, since effective contact times are difficult to achieve due to rapid evaporation.

Table 1. Germicidal Chemicals Recommended for Hepatitis B Virus Decontamination*

Chemical	Concentration	Activity Level
Ethylene oxide gas[1]	450-800 mg/L	High
Glutaraldehyde, aqueous (acid to alkaline)	2 %	High
Stabilized hydrogen peroxide	6-10 %	High
Formaldehyde[2]	3-8 %	Intermediate to high
Hypochlorite[3]	500-5000 mg/L available chlorine	Intermediate
Iodophors[4]	70-150 mg/L available iodine	Intermediate

*Except for ethylene oxide (a sterilizing treatment), contact times should be 10-30 minutes. Quaternary ammonium compounds are not recommended for specific site decontamination since these compounds are not broad spectrum in germicidal activity and their effects on HBV or "AIDS virus" are unknown. Although alcohols (ethyl and isopropyl) are known to inactivate HBV and "AIDS virus," they are not generally recommended since rapid evaporation prohibits effective exposure times. Chemicals listed as "high activity level" are used primarily for total immersion of instruments or objects. In addition to the chemicals listed above, heat in the form of boiling water (98-100° C) for 10-30 minutes is an effective high-level disinfecting treatment for heat-stable materials.

[1]In autoclave-type equipment at 55 to 60° C according to manufacturer's instructions.

[2]Because of the ongoing controversy of the role of formaldehyde as a potential carcinogen, its use is recommended only in limited circumstances under carefully controlled conditions, that is, fixation of tissue specimens or disinfection of "closed systems" such as fluid pathways of hemodialysis systems.

[3]Use 500 to 5000 mg/L depending upon the cleanliness of the surface being treated. These concentrations are easily prepared by diluting sodium hypochlorite (household bleach) 1:100 or 1:10, respectively, in tap water. Ideally, the solution should be made fresh daily. Hypochlorite solutions are corrosive to some metals, especially aluminum.

[4]Use only those iodophors registered with the EPA as disinfectants. Follow manufacturer's directions closely regarding dilution. Antiseptic iodophors (commonly povidone-iodine) should NOT be used as disinfectants. See Favero (1982) for details of the current iodophor controversy.

DECONTAMINATION

In high-risk areas such as laboratories, one is confronted with the problem of decontaminating large and small blood spills on large, smooth surfaces such as floors or bench tops. Also, frequently touched surfaces, for example, instrument control knobs, racks, or precision pipettes, may play a role in environmentally mediated hepatitis if they are manipulated in an improper manner. The strategies for applying the principles of hepatitis B virus inactivation vary according to the item or surface being considered, its potential role in the risk of hepatitis B transmission, and to a certain extent, the thermal and chemical lability of the surface or instrument. For example, if a blood spill occurred on the floor or a counter top in a laboratory, the objective of the procedure to inactivate the hepatitis B virus would be one of decontamination or disinfection and not sterilization. Consequently, in such an instance it is recommended that gloves be worn and the spill be absorbed with disposable towels. The spill site should first be cleaned of all visible contamination and then the area should be wiped down with clean towels wetted with an appropriate high-level or intermediate-level disinfectant (Favero 1980), for example, a dilution of commercially available household bleach (sodium hypochlorite). All soiled towels should be placed in a container which can either be placed with the infectious waste of that particular department or, since it is sometime easier, autoclaved. The concentration of disinfectant used will depend primarily on the type of surface that is involved. For example, in the case of a direct spill on a porous surface that cannot be physically cleaned prior to disinfection, 0.5% sodium hypochlorite (5000 mg available chlorine/liter) should be used. Conversely, if the surface is hard and smooth and has been cleaned appropriately, then 0.05% sodium hypochlorite (500 mg available chlorine/liter) is sufficient.

For purposes of illustration, if an item in question is a medical instrument that is classified as semi-critical (Favero 1980), such as a flexible fiberoptic endoscope (Bond and Moncada 1978), it is extremely important that meticulous physical cleaning precede the sterilization or high-level disinfection procedure. This would be true whether or not ethylene oxide gas sterilization is employed or a high-level chemical disinfection procedure with a contact time of 10-30 min is used.

There are other types of frequently touched environmental surfaces which could be classified as intermediate between non-critical and semi-critical (Favero 1980) such as control knobs on hemodialysis systems. Ideally, in these types of environments, gloves should be worn to avoid "finger painting" of blood contamination and to avoid percutaneous exposure. Further, these surfaces should be routinely cleaned and disinfected using cloths or, if necessary, swabs. In any case, the objective is to reduce the level of hepatitis B virus contamination to such an extent that disease transmission is remote. In a practical sense, this could mean that, after cleaning, a cloth soaked in either 0.05% sodium hypochlorite or a disinfectant-detergent can be used. In this context, the element of physical cleaning is as important as, if not more important than, the choice of the disinfectant. It obviously would not be cost effective or in many cases even feasible to attempt to achieve sterilization or high-level disinfection in all instances.

GENERAL HOUSEKEEPING PROCEDURES

As a common rule, routine daily cleaning procedures that are used for general microbiologic laboratories can be used for laboratories where blood specimens are processed. Obviously, special attention should be given to visibly contaminated areas or items. Further, cleaning personnel must be alerted to the potential hazards associated with such contamination. Floors and other environmental surfaces contaminated in this manner should be thoroughly cleaned with a germicide-disinfectant registered with the U.S. Environmental Protection Agency as a "hospital disinfectant" that is

mycobactericidal. Germicides that are mycobactericidal are preferred because mycobacteria represent one of the most resistant groups of microorganisms; therefore, germicides that are effective against mycobacteria will be effective against most other bacterial, fungal and viral pathogens as well. Gloves should be worn by cleaning personnel doing these duties. However, in the case of large blood spills as mentioned above, this type of procedure may have to be augmented by specific site decontamination using a more effective chemical agent.

SUMMARY

Type B hepatitis is one of the most frequently reported laboratory-associated infections, and clinical laboratorians involved with handling blood or serum are at increased risk of acquiring this disease. The primary modes of transmission are direct contact with blood and serum specimens or by indirect contact with contaminated environmental surfaces. The presence of even small amounts of blood or serum on hands, whether from direct or indirect sources, can result in the hepatitis B virus gaining access to the vascular system by needle sticks, cuts and abrasions, or via nasal, oral, or ocular exposure. Infection control strategies should stress proper techniques for handling blood and containers, appropriate use of gloves, protective clothing and eye protection, frequent handwashing, good personal hygienic practices and the effective use of cleaning, disinfecting and sterilization techniques.

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NOTE: The Centers for Disease Control references, Morbidity Mort. Weekly Rep., are available from the U. S. Government Printing Office. The address is in the Editorial Column on page 3.

BIOCHEMICAL AND IMMUNOCHEMICAL TEST METHODS: POINTS TO CONSIDER FOR ASSOCIATE AND GENERAL REFEREES

FOREWORD

Practitioners in the forensic science community have a responsibility to insure that methods employed in the examination of physical evidence are subjected to appropriate scientific scrutiny aimed at establishing the reliability and validity of the test method. There is much discussion as to what the form or process of such scrutiny should be. In the following article, some of the recommended criteria or "points for consideration" are presented which might be applied to biological/biochemical/immunochemical test methods.

Dr. O'Rangers is currently a research biochemist in the Drugs, Devices and Radiological Health Branch of the Food and Drug Administration. He previously worked in the immunodiagnostics industry at Princeton Laboratories, a subsidiary of Carter-Wallace. In his voluntary role as General Referee for the subject area, "Diagnostics," he recommends topic areas for methods studies and provides guidance and coordination to the individual Associate Referees responsible for carrying out those studies.

I wish to thank Dr. O'Rangers for allowing this report to be published in the Crime Laboratory Digest.

John W. Hicks
Chief, Scientific Analysis Section
FBI Laboratory

FEATURE ARTICLE

BIOCHEMICAL AND IMMUNOCHEMICAL TEST METHODS: POINTS TO CONSIDER FOR ASSOCIATE AND GENERAL REFEREES

John J. O'Rangers

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The validation and collaborative study of analytical methods have traditionally been viewed as distinct processes. This view has led to confusion in the purpose and design of collaborative studies since it seems to be commonly accepted that validation precedes collaboration and the two elements are separate and distinct procedures. This view finds its expression in the idea that validation tests should not be part of a collaborative study, since the traditional view holds that the collaborative study should show method ruggedness of transferability as its main goal.

While it is quite true valuable voluntary collaborative study time should never be expended on methods which have been poorly developed or inadequately validated at the developmental stage, it is equally true validation tests are part of any collaborative study. It should be clearly understood that certification of analytical methodology involves both intra- and inter-laboratory studies. The key element in these studies is the design of the validation protocols used in the laboratory testing of the methodology. Collaborative studies are therefore, a type of validation study whereby method performance including transferability can be measured.

The following are points for consideration in study design that may be of use to referees in the biological/biochemical/immunochemical areas.

Associate Referees

A. Before a potential method is submitted to collaborative study, intra-laboratory validation of the complete method should be done. The results of the validation trials should be available for discussion with the general referee prior to collaborative study.

Keep in mind that at a minimum, the purposes of intra-laboratory validation studies are to:

1. Determine when the method is optimized,
2. Identify critical method steps,
3. Recognize and solve interferences,
4. Assess method performance using authentic sample,
5. Show that spiked samples emulate authentic samples if authentic samples cannot be used, and
6. Compare results with other techniques, if appropriate.

B. Some specific points for consideration in biochemical validation protocol design:

1. Comparison of statistics and data obtained on the same sample assayed with different critical reagent preparations.

   Purpose: To observe precision over a projected time span and to identify reagent variables. Examples of some critical reagents would be enzyme or antibody preparations.

2. Test Linearity

   Purpose: To validate that an analytical response is linear with analyte measured. Depending on assay test design, linearity can also yield information on test specificity.

3. Recovery Studies

   Purpose: To demonstrate that the added constituent is recoverable in the assay system. Recovery studies should be done at each major step in the extraction and clean-up procedure. This will help to identify critical steps and assist in optimizing conditions of assay.

Recovery should be based on the relationship between added and recovered constituent not on the predicted assay value and the observed value.

4. Determine stability of critical test reagents and spiked samples over time and defined temperatures.

   Purpose: To determine stability of critical reagents and potential instabilities conferred on the analyte by the matrix.

5. Determine limit of measurement (sensitivity)

   Purpose: A basic analytical parameter.

6. Determine method specificity using cross-reactants and other interfering substances at levels and in matrix combinations that are expected to occur in practice.

   Purpose: To establish conditions under which reliable measurement can be expected.

7. Determine if possible, method performance with authentic samples.

   Purpose: To establish method workability with actual samples expected to be encountered in practice.

If the laboratory scientist is the associate referee for a commercially manufactured kit or reagent, I recommend at minimum, the following information be secured:

1. Complete description of test or reagent,
2. Protocol for validation,
3. Data on interferences,
4. Known stability data,
5. Cross-reactivity data,
6. Matrices to which applied,
7. Precision data, and
8. Sensitivity.

General Referees

In general, there are five important method performance measures that the general referee should ensure are addressed in the collaborative study design.

A. Concentration range of analysis and linearity,
B. Limits of measurement (sensitivity),
C. Accuracy,
D. Specificity (interferences and matrix effect also), and
E. Reproducibility.

REGIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

The Northwestern Association of Forensic Scientists (NWAF) will hold their Spring 1986 meeting at the Inn of the Seventh Mountain in Bend, Oregon from April 29 - May 2, 1986.

For further information contact Michael A. Howard, Oregon State Police Crime Laboratory, 375 N.E. Franklin Street, Bend, Oregon 97701 (telephone: 503-388-6150).

The California Association of Criminalists (CAC) will hold their semi-annual seminar at the Hilton Hotel in Concord, California from May 14-17, 1986. This seminar will be hosted by the Contra Costa County Sheriff's Office Criminalistics Laboratory.

For further information contact Kathy Holmes, Contra Costa Sheriff-Coroner, 729 Castro Street, Martinez, California 94553 (telephone: 415-372-2962).

A combined meeting of the Southern Association of Forensic Scientists (SAFS), the Southwestern Association of Forensic Scientists (SWAFS), the Mid-Atlantic Association of Forensic Scientists (MAAFS), the Midwestern Association of Forensic Scientists (MAFS), and the Northeastern Association of Forensic Scientists (NEAFS) will be held May 27-31, 1986 at the Radison Hotel in Lexington, Kentucky.

Among the planned activities are workshops, section meetings and laboratory safety training. A computer workshop and an isoelectric focusing workshop are scheduled for May 28, 1986. A 17-hour Basic Laboratory Safety Training Workshop will be conducted by the Occupational Health and Safety Administration on May 27-28, 1986. Section meetings in criminalistics, drugs, toxicology and serology will be held.

For further information contact Harold M. Alfultis, Loraine County Crime Lab, 1005 North Abbe Road, Elyria, Ohio 44035 (telephone: 216-365-4191, ext. 364).

NATIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

The 38th Annual Meeting of the American Academy of Forensic Sciences is scheduled for February 11-15, 1986. The meeting will be held at the Hyatt Regency Hotel in New Orleans, Louisiana.

For further information contact the American Academy of Forensic Sciences, 225 S. Academy Boulevard, Colorado Springs, Colorado 80910 (telephone: 303-596-6006).

The Bureau of Alcohol, Tobacco and Firearms (ATF) will conduct two Accelerant Detection Classes in 1986 for state and local forensic examiners. The classes are scheduled for June 9-13 and July 14-18. Enrollment is limited to 10 students per class.

The one-week course, conducted at the ATF National Laboratory Center (NLC) in Rockville, Maryland, emphasizes hands-on laboratory analysis utilizing all of the sample preparation techniques in common use today for arson examination. Lectures and discussions cover classifying accelerants, developing your own analysis scheme, accelerant comparison techniques, use of analytical techniques other than gas chromatography, pre-analysis clean-up techniques and proper evidence handling.

The course has been updated to place more emphasis on the interpretation of data. An additional practical excercise has been added. Recognition of incendiary devices and components has also been added.

The course is designed for state and local chemists who perform, or will be performing, laboratory arson analysis. There is no tuition or registration fee, and all course materials are provided at no cost to the attendee. All transportation, lodging, and per diem costs must be borne by the local department or individual. Budgeting $75 per day should cover lodging and meal costs. The ATF Laboratory will arrange a group rate for all selected students as a hotel convenient to the NLC.

Those persons interested in applying can

obtain an application from their ATF district office or by contacting Rick Tontarski at ATF NLC, 1401 Research Boulevard, Rockville, Maryland 20850 (telephone: 202-294-0420). The application deadline is March 3, 1986. Applicants will be notified of their selection in April.

A symposium on forensic chemistry will be held in conjunction with the Annual Federation of Analytical Chemistry and Spectroscopy Societies Meeting from September 28 - October 3, 1986 at the Cervantes Convention Center in St. Louis, Missouri. Special consideration will be given to presentations discussing forensic applications of infrared and atomic spectroscopies, but other topics will be considered. The deadline for submitting titles is February 3, 1986.

For further information about the symposium contact Dr. Robert Koons, FSRTC, FBI Academy, Quantico, Virginia 22135 (telephone: 703-640-6131).

INTERNATIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

The Pan American Forensic Sciences Institute (P.A.F.S.I.) will host a symposium entitled "First Annual Pan American Forensic Sciences Symposium." The symposium will be held in Ixtapa, Zihuatanejo, Mexico from January 15-18, 1986. The symposium will be devoted to lectures on toxicology, serology, legal implications, psychiatry, anthropology, odontology and more. This symposium meets the criteria for 26 hours of Category II of the Physician's Recognition Award of the American Medical Association.

The course tuition is $365 (U.S. dollars) and includes registration and materials, seafood buffet, certificate of attendance, diploma and subscription to the P.A.F.S.I. Newsletter. Hotel accommodations for five days and four nights are $220 for single occupancy and $256 for double occupancy.

For further information contact Dr. P.C. Lippa, Director, Pan American Forensic Sciences Institute, 8383 Wilshire Boulevard, Suite 230, Beverly Hills, California 90211. Telephone inquiries will be taken by Betty Feinberg, Secreatary-Treasurer of P.A.F.S.I. at 818-886-0341. Collect calls will be accepted.

The Federal Bureau of Investigation will host a symposium entitled "An International Symposium on Driving Under the Influence of Alcohol and/or Drugs." The symposium is scheduled for March 24-26, 1986 at the FBI Academy in Quantico, Virginia. The symposium will be devoted to short papers, poster sessions, and/or discussions of pertinent research, training, scientific data and testimony topics. Plenary sessions will be devoted to lectures by prominent experts on the pharmacology of drugs of interest, analysis of drugs and metabolites in biological specimens, and legal aspects of driving under the influence of alcohol and/or drugs.

Individuals from forensic laboratories, academia and other scientists are encouraged to submit abstracts on the identification, testing and prosecution of individuals driving under the influence of alcohol and/or drugs. Abstracts should be forwarded by December 1, 1985 to SA Kenneth W. Nimmich, Symposium Coordinator, FSRTC, FBI Academy, Quantico, Virginia 22135 (telephone: 703-640-6131, ext. 3307).

The Federal Bureau of Investigation will host a symposium entitled "An International Symposium on Digital Image Processing for Forensic Applications." The symposium is scheduled for June 15-20, 1986 at the FBI Academy in Quantico, Virginia. The symposium will be devoted to technical papers on techniques and methodology in examining forensic images.

For further information contact SA Michael G. Noblett, Laboratory Division, J. Edgar Hoover FBI Building, 10th and Pennsylvania Avenue, N.W., Washington, D.C. 20535 (telephone: 202-324-4427).

The Federal Bureau of Investigation will host a symposium entitled "An Inter-

national Symposium on Forensic Immunology". The symposium is scheduled for June 23-26, 1986 at the FBI Academy in Quantico, Virginia. The symposium will provide a forum for the discussion of techniques and issues relevant to the immunological analysis of body fluid evidence. Plenary sessions will be devoted to lectures by prominent scientists on forensic immunological topics such as the immune response, antibody-antigen interactions, immunofixation methods, monoclonal antibodies, ELISA, individualization and quality assurance. Afternoon sessions will be devoted to short papers, poster sessions and/or discussions of pertinent research, training, scientific data and testimony topics.

Individuals from forensic laboratories and academia are encouraged to submit abstracts of original research concerning new developments or applications in the area of forensic immunology. Abstracts should be forwarded by February 28, 1986 to SA Kenneth W. Nimmich, Symposium Coordinator, FSRTC, FBI Academy, Quantico, Virginia 22135 (telephone: 703-640-6131, ext. 3307).

The Japanese Society of Electron Microscopy and the Science Council of Japan will host the XIth International Congress on Electron Microscopy (XI ICEM). The congress is scheduled for August 31 - September 7, 1986 in the Okazaki area of the city of Kyoto. The congress will be devoted to plenary sessions, symposia, workshops, public lectures and poster and/or oral presentations of contributed papers. Emphasis will be placed in the poster sessions. Symposia and workshops on recent topics in the technology and application of electron microscopy are among the scheduled activities. The official language of the XI ICEM is English. Deadline for submission of abstracts is March 31, 1986.

For information contact Professor Kazuo Ogawa, Chairman, Executive Committee of the XI ICEM, Department of Anatomy, Faculty of Medicine, Kyoto University, Konoecho, Yoshida, Sakyoku, Kyoto 606, Japan (telephone: 075-751-7727; telex: 05422693 LIBKYU J)

The International Association of Forensic Toxicologists will hold their 8th triennial meeting in Banff, Alberta, Canada in July 1987.

For further information contact N. Dunnett, Home Office Forensic Science Laboratory, Aldermason, Berkshire, RG7 4PN, UK.

The International Association of Forensic Sciences will hold their 11th meeting at the Hotel Vancouver in Vancouver, British Columbia, Canada from August 2-7, 1987. The meeting will be structured around plenary sessions, short paper sessions, technical exhibits, poster sessions, and an arts and crafts exhibition. Special presentations by the International Academy of Legal Medicine and Social Medicine, and the International Study Group on National Unexpected Deaths are scheduled for the meeting. Plenary sessions include Collection and Presentation of Evidence, Conduct of a Criminal Trial and Sentencing the Offender.

Abstracts should be forwarded by December 31, 1986 to the International Association of Forensic Sciences, Suite 801, 750 Jervis Street, Vancouver, British Columbia, Canada V6E 2A9 (telephone: 604-681-5226).

INSTRUCTIONS FOR SUBMITTING ARTICLES

In order to facilitate rapid publication, submissions should conform to the following:

1. Manuscripts should be typed, double-spaced, on 8½" × 11" paper. Submit three copies of the manuscript (one of which must be the original with glossy photographs).

2. Tables should be as simple as possible. Each table should be typed on a separate sheet of paper and should include a heading.

3. Graphs and diagrams should be submitted as sharp photographs on white glossy paper.

4. References in the body of the paper should refer to the author's (authors') name(s) and the date of publication. For example:
   According to Doe and Smith (1972) . . .

   . . . has been discussed in the literature (Doe and Smith 1972; Weinburger et al. 1984; Jones 1981).

5. References at the end of the paper should appear in alphabetical order. Journal references should include the author's (authors') name(s), date of publication, title of the article, journal, volume number, and the beginning and ending pages of the article. Please follow the format below.

   Davis, H. E. and Jones, B. A. (1978). Seasonal variations in plasma hormones, Biol. Reprod. 88:271-273.

   List articles or chapters within a book as follows:

   deHaseth, J. A. (1982). Fourier transform infrared spectrometry. In: Fourier, Hadamard and Hilbert Transformations in Chemistry, (Marshall, A. G., ed.) Plenum Press, New York, pp. 387-420.

6. Technical papers should be written in an Introduction, Materials and Methods, and Results and Discussion format.

7. When reference is made to a particular product, state the manufacturer of the product and the city and state of the manufacturer's headquarters. For example:

   Isotactic PS (Dow Chemical, Midland, MI) . . .

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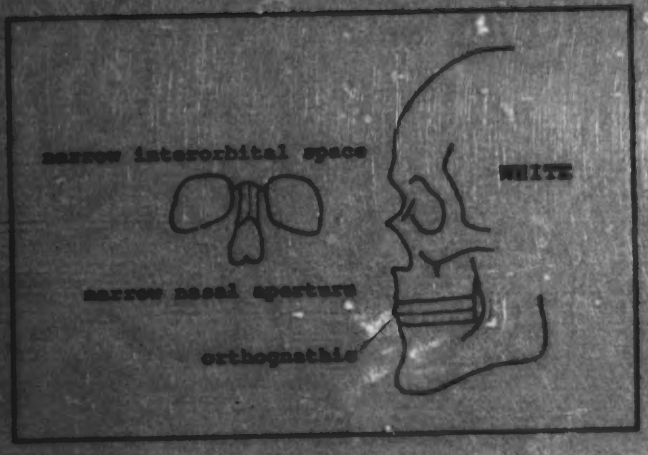

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The Crime Laboratory Digest is published quarterly by the FBI Laboratory in cooperation with the American Society of Crime Laboratory Directors (ASCLD). It is intended to serve as a rapid means of communication between crime laboratories, permitting information of interest and value to be disseminated among crime laboratory scientists.

Inclusion of an article in the Crime Laboratory Digest in no way represents an endorsement or recommendation of any part of that article by the Federal Government, the Department of Justice or the FBI. Contributing authors assume total responsibility for the contents and accuracy of their submissions. Questions or requests concerning an article should be directed to the contributing agency.

All submissions are subject to editorial review in accordance with the editorial policy established by the FBI Laboratory and ASCLD. The editorial staff of the Crime Laboratory Digest reserves the right to edit all articles for style, grammar and punctuation. Comments and letters to the editor are encouraged and will be published when appropriate and as space permits. These should be forwarded to:

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ON THE COVER

The cover, prepared by the Special Projects Section of the FBI Laboratory illustrates cartilage growth plates of unfused epiphysis, and White and Black cranial morphology.

MESSAGE FROM THE ASSISTANT DIRECTOR IN CHARGE OF THE FBI LABORATORY

Since meeting with the members of the American Society of Crime Laboratory Directors in September 1985 at the FBI Academy, Quantico, Virginia, I have had additional opportunities to meet with other members of the forensic science community as well.

In February of this year, I attended the American Academy of Forensic Sciences meeting in New Orleans, Louisiana, and was very pleased to visit with members of the Academy. It is hoped the FBI Laboratory's association with the Academy will continue to provide for a mutual exchange of information and research which is necessary to best aid the law enforcement community in its efforts to solve the critical criminal problems facing us all.

The FBI welcomes the exchange of information and research with the Academy and the other forensic science associations. Laboratory personnel at the FBI are especially encouraged to make presentations at the various regional forensic science association meetings and to maintain liaison with these associations. The presentations made by FBI staff may range from a discussion of a specific technique to general information about the FBI Laboratory.

In March, I attended a symposium entitled, "An International Symposium on Driving Under the Influence of Alcohol and/or Drugs" which was held at the FBI Academy. Forensic scientists from the law enforcement community, research scientists from academia, and other pertinent experts discussed the identification and testing for alcohol and drugs as well as the effects of these substances on the driver.

Driving under the influence of alcohol and/or drugs is a crime of serious proportions in the United States. In 1984 (most recent data available, Uniform Crime Reports) the total arrests for driving under the influence in the United States was 1,346,586. Information obtained from the National Highway Traffic Safety Administration indicated that in 1984 there were 44,241 traffic fatalities. Despite the fact that the yearly number of traffic fatalities has decreased in the past few years, the proportion of those deaths that are attributed to alcohol is over 50 percent (23,500) and remains a major public safety concern. By hosting this symposium, we at the FBI Laboratory are pleased to make a contribution to this public safety effort.

In June 1986, I plan to attend two additional international symposia. The FBI Laboratory is hosting an International Symposium on Forensic Immunology, June 23-26, 1986, at the FBI Academy. It will be an opportunity for me to visit with individuals from forensic laboratories and academia that are developing new methodologies for analyzing physical evidence containing body fluids. I also will be attending the 2nd International Symposium on Analysis and Detection of Explosives, June 29-July 3, 1986, in Neurim, Israel. Interestingly, the 1st International Symposium on Analysis and Detection of Explosives was hosted by the FBI Laboratory at our Academy in 1983 and was the first international symposium hosted by the FBI Laboratory. It is at meetings such as these symposia that experts in specific disciplines can interact and provide the forensic community with the latest developments in forensic analyses. The FBI Laboratory will continue to support these types of programs by both hosting symposia and participating as a member of the international forensic community in symposia sponsored by other countries.

ROBERT S. GAST II

To assist in our efforts to maintain a current directory of all forensic laboratories serving the criminal justice system in the United States, please return the response card found in the center of this issue of the Crime Laboratory Digest (Note: This response card will only be found in those copies of this publication mailed to organizations in the United States). Your assistance will enable the FBI to disseminate information (formal announcements of symposia, lists of classes offered at the FBI Academy, etc.) to all forensic laboratories in the United States.

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON THE FORENSIC APPLICATIONS OF ELECTROPHORESIS

The "Proceedings of the International Symposium on the Forensic Applications of Electrophoresis" is now available for $8.00 (foreign delivery $10.00) through the U.S. Government Printing Office (GPO). The GPO stock number for this publication is 027-001-00039-4. Requests for this publication should be directed to:

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

This 200-page publication is the result of a symposium held at the Forensic Science Research and Training Center, FBI Academy, Quantico, Virginia, June 26-28, 1984. This publication contains manuscripts from 14 plenary lectures on topics such as "Genetics, Forensics and Electrophoresis," "Why Polymorphisms Occur?," Electrophoretic Theory and Practice: Opinions in Electrophoretic Analysis" and "Standards for Forensic Electrophoresis." There are also 20 extended abstracts and 10 short abstracts on electrophoretic techniques. Additionally, there are summaries of two panel discussions: "Electrophoretic Systems - Single, Multi and Isoelectric Focusing" and "Method Reliability".

CENTRAL RESEARCH ESTABLISHMENT REPORTS

The Central Research Establishment (CRE), Home Office Forensic Science Service, Aldermaston, Reading, England, has provided the FBI Laboratory with copies of CRE Reports on completed research projects. By mutual agreement between the FBI and the CRE, these reports are available to all duly authorized law enforcement organizations in the United States. To obtain these reports, send a request from your crime laboratory director to:

Federal Bureau of Investigation
Colleen Wade, Librarian
Forensic Science Information
Resource System
Room 3589
10th and Pennsylvania, N.W.
Washington, D.C. 20535

The following CRE Reports are now available:

The Significance of the Levels of ABH Blood Group Substances in the ABO Groupings of Saliva, Shaw, I. C., Whitehead, P. H. and Lang, B. G., CRE Report #435.

High-Performance Liquid Chromatography of Paraquat and Diquat in Urine with Rapid Sample, Gill, R., Qua, S. C. and Moffat, A. C., CRE Report #442.

The Detection of Prostatic Acid Phosphatase in Vaginal Swabs in Radioimmunoassay, Dorrill, M. J., Dolton, P. J. and Fletcher, S. M., CRE Report #444.

Sample Loss During Routine Preparation for Microscopy, Peabody, A. J. and Burgess, R. M., CRE Report #446.

A Collection of Therapeutic, Toxic and Fatal Blood Drug Concentrations in Man, Stead, A. H. and Moffat, A. C., CRE Report #449.

The Persistence of Military Explosives on Hands, Twibell, J. D., Turner, S. L. and Smalldon, K. W., CRE Report #451.

Development and Evaluation of a Radioimmunoassay for the Detection of Amphetamine, Mason, P. A., Bal, T. S., Law, B. and Moffat, A. C., CRE Report #455.

The Efficient Extraction of Some Common Organic Explosives from Swabs for Analysis, Twibell, J. D., Wright, T. and Sanger, D. G., CRE Report #456.

A Survey of Class Fragments Recovered from Clothing of Persons Suspected of Involvement, Harrison, P. H., Lambert, J. A. and Zoro, J. A., CRE Report #458.

Spectrophometric Measurements on Dried Bloodstains, Laing, D. K. and Shaw, I. C., CRE Report #460.

A Rapid General Method for Extracting Benzodiazepines from Small Blood Samples, Stevens, H. M., CRE Report #463.

Inductively Coupled Plasma-Optical Emission Spectrometry, Carpenter, R. C., CRE Report #466.

The Feasibility of Using the Johne and Reilhofer ER10 Colorimeter, Cousins, D. R., Davies, P. A., Jenkins, C. M., Russel, L. W. and Shah, K., CRE Report #585.

A Collaborative Study to Investigate the Retention Reproducibility of Barbiturates in HPLC, Gill, R. and Moffat, A. C., CRE Report #586.

Forensic Application of DNA "Fingerprints," Gill, P., Jeffreys, A. J. and Werrett, D. J., CRE Report #587.

Subtyping of Ultra-Thin Isoelectricfocusing and Immobilised pH Gradients, Nelson, L. and Werrett, D. J., CRE Report #588.

The Evidential Value of Dispersion in the Examination of Glass, Locke, J. and Perryman, A. C., CRE Report #589.

REVIEW ARTICLE

ANTHROPOLOGY AS APPLIED TO FORENSIC SCIENCE

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In 1849, Dr. George Parkman, a prominent Boston physician, was murdered by Dr. John White Webster, a professor of chemistry at Harvard University. Professor Webster, having borrowed a large sum of money from Dr. Parkman, became delinquent in repayment. In desperation, Dr. Parkman resorted to public dunning and had even become a front row attendant in some of Professor Webster's classes. Professor Webster, embarrassed and agitated by these tactics, chose to permanently cancel his debt as well as Dr. Parkman. To cover the crime, Dr. Parkman's body was disarticulated and partially incinerated in a laboratory furnace at Harvard (Snow 1973). Unfortunately for Professor Webster, fate had picked that particular time to give birth to a new science -- Forensic Anthropology.

The name Forensic Anthropology was not applied to this science until almost a century later, and it was not until the early 1970s that it was formally recognized as a subdiscipline of Physical Anthropology. In fact, Physical Anthropology was not an organized discipline in the United States during the late Nineteenth Century. In the Parkman case, for example, the skeletal remains were examined by Dr. Jeffries Wyman, Hersey professor of anatomy at Harvard, and Dr. Oliver Wendell Holmes, anatomist and dean of the Harvard Medical School. The remains were verified as Parkman on the basis of estimates of age, stature and denture fragments from the furnace (Snow 1973).

Forensic Anthropology deals with the identification of skeletonized or partially skeletonized human remains for official agencies either as isolated cases or in mass disasters such as air crashes. Once the remains are determined to be human, the anthropologist closely examines each bone to provide estimates of age, sex, race and stature, and documents any unique trait that may be pertinent in establishing a positive identity. Since 7 to 10 years are usually required before a missing person can be declared dead, the identification of skeletal remains provides emotional relief to the next-of-kin, and is an essential legal element of the *corpus delicti* -- a welcome piece of evidence for any prosecuting attorney.

The ability to identify an individual from his or her skeletal remains is often attributed an undue aura of mystery by the lay person. In practice, identification is based on an understanding of the biology of skeletal growth, development, maturation, degeneration and sexual dimorphism. The anthropologist must possess a thorough knowledge of skeletal anatomy and the factors responsible for human variation.

AGE ESTIMATION

Aging techniques for subadult remains are derived from skeletal and dental changes occurring during growth and development. Long bone growth (that is, bones of the arms and legs) occurs at cartilage growth plates that separate the diaphysis or shaft portion from the epiphysis or end portion of the bone (Figure 1). Disappearance of these cartilage plates with the resulting fusion of the epiphysis to the shaft, mark the end of growth at a particular site. The age at which epiphyses fuse has been determined for different bones (McKern and Stewart 1957). Long bone length has been correlated with age and illustrations have been developed that facilitate age estimation from measurements of bone length (Hoffman 1979; Merchant and Ubelaker 1977; Stewart 1954). Avenues for subadult age estimation are also offered by the eruption times of deciduous and permanent teeth (Schour and Massler 1941, 1944), and the development of tooth crown and root as viewed radiographically (Moorrees *et al.* 1963a, 1963b).

In adults, the investigator must depend on degenerative changes; and one of the most commonly used techniques of this type is based on the metamorphosis of the pubic symphysis. In the young adult, the symphyseal face is characterized by a billowed or rounded appearance. With age, the billowed features disappear leaving a relatively flat surface. By the fifth decade

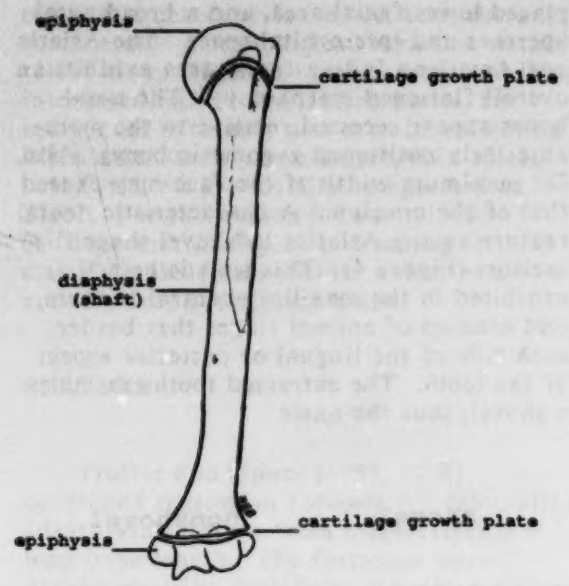

FIGURE 1. Humerus illustrating cartilage growth plates of unfused epiphysis.

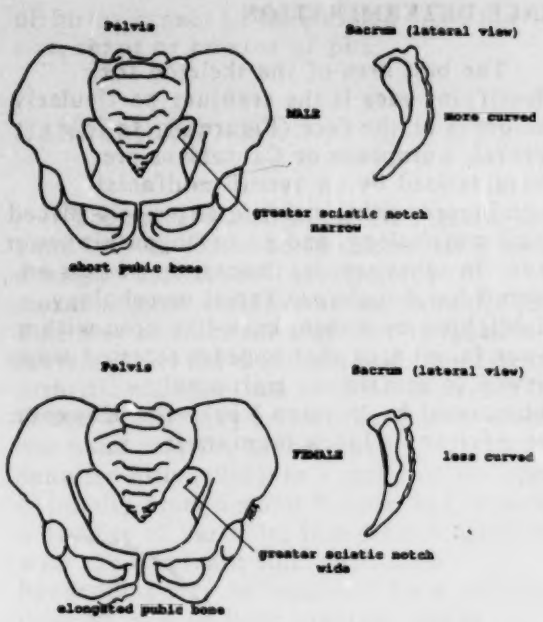

FIGURE 2. Male and female pelvic morphology.

of life, the symphysis exhibits arthritic changes of erosion and occasionally sporadic osteophytic growth. These changes have been defined for males (Todd 1920; McKern and Stewart 1957) and females (Gilbert and McKern 1973), and serve as helpful tools for the forensic anthropologist. Changes in bone microstructure have also been correlated with age (Kerley 1965, 1969, 1970). Of the available aging methods, error may range from 2 years below the age of 30, to 5 years between 30 and 40, and 10 or more years for those in the upper age groups. When determining age in a forensic situation, as many indicators as possible should be used.

SEX DETERMINATION

The skeletal elements that most accurately reflect sex are those comprising the pelvic girdle (Figure 2). The female pelvis is "designed" to accommodate birth, and is characterized by a larger pelvic outlet than the male. Some of the features contributing to this difference are elongated pubic bones, a more open greater sciatic notch, a wider and less curved sacrum, and an elevated sacroiliac articulation (Bass 1971; Krogman 1962; Stewart 1979). Second in importance for determining sex is the cranium. The male skull is larger and possesses more robust features than that of the female.

In addition to these directly observable features, a variety of metric techniques are available that reflect both size and shape differences. These range from single measurements of femur and humerus head diameter (Dwight 1905; Pearson 1919; Thieme 1957) to indices such as the ischiopubic index (Washburn 1948), or to the more sophisticated multivariate statistical techniques as developed on the cranium, mandible or post cranial bones (Giles 1964, 1970; Giles and Elliot 1963). Regardless of the technique used, the possibility of error always exists. For this reason, the anthropologist usually employs a variety of techniques when determining sex.

RACE DETERMINATION

The best area of the skeleton for identifying race is the cranium, particularly the bones of the face (Figure 3). In general, Europeans or Caucasians are characterized by an overall midfacial prominence with a narrow, anteriorly placed nasal morphology, and an orthognathic lower face. In other words, Caucasians possess an overall hatchet-shaped facial morphology, highlighted by a thin, beak-like nose with a lower facial area that appears recessed when viewed in profile -- a trait amply appreciated by Norman Rockwell. However, the African or Black cranium is characterized by a prognathic or anteriorly placed lower facial area, and a broad nasal aperture and interorbital space. The Asiatic and American Indian facial area exhibits an overall flattened morphology. The nasal bones appear recessed relative to the more anteriorly positioned zygomatic bones. Also, the maximum width of the face may exceed that of the cranium. A characteristic dental feature among Asiatics is "shovel-shaped" incisors (Figure 4). This trait is best exhibited in the maxillary central incisors, and consists of enamel ridges that border each side of the lingual or posterior aspect of the tooth. The extracted tooth resembles a shovel, thus the name.

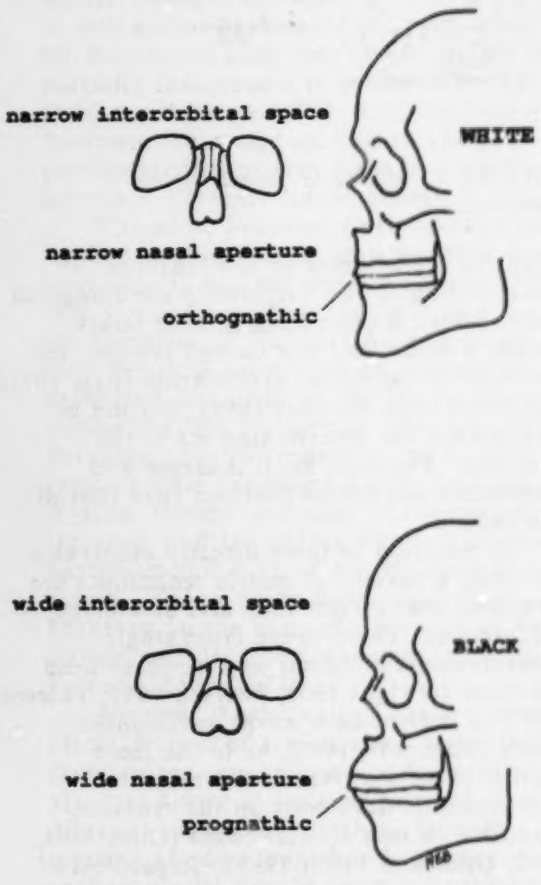

FIGURE 3. White and Black cranial morphology.

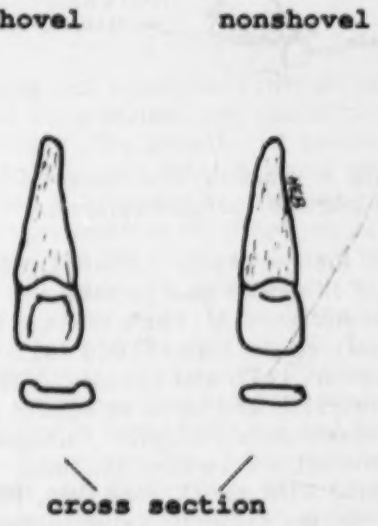

FIGURE 4. Shovel-shaped and nonshovel-shaped central incisor, lingual view.

Discriminant function analysis of craniofacial measurements provides a mathematical method of placing an unidentified skull in one of three racial groups (Giles and Elliot 1962). Depending upon the race and the measurements used, Giles (1970) reports a tested accuracy of assignment for American Whites and Blacks at between 83.2 and 88.3 percent. However, this technique was criticized by Birkby (1966) and has recently been reevaluated by Ayers and Jantz (1986).

Race identification from the skeleton requires much experience. At best, there is considerable morphological variation within a racial group which is further complicated by interbreeding. In the United States, an individual with only a few traits reflecting Black admixture (for example, skin color, hair form, etc.) is socially categorized as Black. For this reason Stewart (1979) cautions that it may be misleading to classify a skeleton as White unless it is entirely free from Black traits.

STATURE

Trotter and Gleser (1952, 1958) developed regression formula for calculating adult living stature from measurements of long bone length. The formulae were developed using data from American soldiers killed during World War II and later expanded to include Korean War dead. Since stature is influenced by variables of sex, race and age, Trotter and Gleser developed formulae for each sex and race combination, and further provided a correction equation to adjust for age related stature loss. The fact that bones are often damaged led Steele (1970) to develop formulae for estimating stature from incomplete long bones. At present, no reliable method exists for determining subadult stature directly from the skeleton.

CHILDBIRTH

The site of ligament attachment on the dorsal surface of the pubic symphysis and the sacroiliac joints are subject to rupture and hemorrhage during childbirth. Such trauma produces pits of various sizes and shapes on the dorsal border of the pubic symphysis and in the preauricular grooves of the ilia (Houghton 1974; Stewart 1970). Although these pits are occasionally present among nonchildbearing females and absent among some females of full term pregnancies (Suchey *et al.* 1979), their presence is indicative of the trauma usually resulting from childbirth. However, the exact number of births cannot be determined from the size, shape or number of pits.

HANDEDNESS

The preferential use of the right or left hand may be reflected in side specific bone changes. Stewart (1976) has noted morphological variation in the shoulder joint that may account for a greater range of movement in the dominant arm. Differential arthritic changes such as those described by Ortner (1968) may reflect the greater use of one hand relative to the other. Schulter-Ellis (1980), in a study of the upper extremity from a small sample, has recorded a number of variables that seem to correlate with the dominant side. Although handedness may be suggested from skeletal remains, it is of little practical use in establishing identity -- hand preference is seldom documented in the records of a missing person.

FACIAL RECONSTRUCTION

Artistic skills and talent are a must in this aspect of identification. The production of both a two-dimensional (that is, portrait) and three-dimensional (that is, sculpture) representation of facial features based upon craniofacial morphology has been used, with varying results, in identification cases. The police artist, sculptor, or talented anthropologist must incorporate estimates of age, sex and race directly into a portrait or bust of the questioned person with the underlying bony facial morphology as a guide to the subtleties responsible for individuality. Three-dimensional facial reconstruction is based on a knowledge of tissue thickness at various landmarks of the face, and for this reason may produce more accurate results than a two-dimensional representation. The technique has been favorably evaluated by Snow *et al.* (1970), and Betty Gatliff of Norman, Oklahoma is commonly recognized as the most accomplished facial reconstructionist in the United States. Facial drawings and reconstructions are

usually publicized in hopes that someone will recognize the individual. Recognition alone is not enough to establish a positive identity but provides a starting point from which dental and medical records may be acquired for comparison.

ESTABLISHING SPECIFIC IDENTITY

The determination of such parameters as age, sex and race may be used to narrow the missing persons list from a large number of possibilities to a smaller, more manageable number. Specific characteristics of the unidentified skeletal remains are then compared with dental and medical records of the missing individuals. The dental records are among the first documents sought; however, in their absence, antemortem radiographs and medical records may prove useful. Although radiographs from any area of the body may be used, those of the cranium, chest and abdomen have provided the greatest aid (Murphy *et al.* 1980). Skeletal anomalies, pathologies and postsurgical evidence provide the features or combinations of features needed to uniquely characterize an individual to the probable exclusion of all others. Surgical evidence such as bone grafts or craniotomies (Berryman and Lahren 1985; Sauer and Dunlap 1985) routinely used today may prove helpful. If dental and medical records are not available, photographic superimposition may be employed. With this technique, a photograph of the known individual is compared, by means of superimposition, to a photograph of the questioned cranium.

RECOVERY

In the late 1960s, the term "forensic archaeology" began to appear in the literature (Morse *et al.* 1976) reflecting the increased use of archaeological techniques in forensic recovery. Archaeology is the study of past lifeways through the systematic recovery and interpretation of the material evidence. The archaeologist, through an examination of soil color and texture, can detect disturbed areas where holes or pits were dug days or even hundreds of years earlier. Forensic archaeologic techniques have been used in the recovery of surface remains but can mean a savings of considerable time and expense when specifically searching for buried remains. All material evidence is documented through maps, drawings, photographs and field notes. Once removed, forensic remains and evidence are transported with the same care demonstrated in the transport of a fragile Anasazi ceramic vessel. The use of an archaeologist is more time-consuming than having the law enforcement agency simply collect the remains; however, the thoroughness of recovery, enhancement of interpretative potential, and credibility in a courtroom setting make this a worthwhile investment.

TIME OF DEATH

A rough indication of the time of death may be estimated by the amount of soft tissue present with the remains or the presence and intensity of odor. However, the rate of decomposition is complicated by a complex array of variables including temperature, rainfall, and access to scavenger and insect activity. Entomologists and botanists may be consulted for a more exact temporal placement of death. The presence of adult insects, pupae or larvae on the remains may be identified according to species, and the knowledge of the time required for a given species to reach a certain metamorphic stage may indicate the minimum time since death (Rodriguez and Bass 1983). In addition, a knowledge of botany may be used to age vegetation that has overgrown or intruded into the remains (Willey and Heilman 1986).

CONCLUSION

The anthropologist of today, if handed the few scraps of bone belonging to Dr. Parkman, could extract a considerable amount of data. Since Professor Webster --

with the aid of the executioner's rope -- bid farewell to the trouble and debts of this life, the search for new forensic anthropology techniques and the improvement of old ones have been ongoing. Many of the "traditional" techniques were developed on anatomic specimens acquired during the early part of this century. Due to an increase in the quality of life in this country, these early study series may not be representative of contemporary populations (Stewart 1980).

A data base, obtained from modern forensic cases of documented identity, is currently being established under the direction of Dr. Richard Jantz. From this effort, standards that more adequately characterize modern populations will be derived for determining parameters such as age, sex, race and stature. Suchey (1979, 1985) has reevaluated the pubic symphysis aging technique using large series of pubic bones collected at autopsy while others have explored new methods of aging such as the ossification of the sternal ends of the ribs (McCormick 1980; Iscan *et al.* 1984, 1985) and the microstructure of tooth roots (Mincer *et al.* 1983; Condon *et al.* 1985). Lovejoy *et al.* (1985) have developed a multifactoral approach to aging the adult skeleton that incorporates the pubic symphyseal face, auricular surface, radiographs of the proximal femur, dental wear and suture closure as a means of increasing accuracy. In addition, some anthropologists have specialized in relatively unique areas ranging from analysis of footprints (Robbins 1978) to earprints (Brues 1986). Forensic Anthropology evolved from an occasionally used expertise a century ago to a recognized body of experts who subject themselves to peer scrutiny through board certification. Diplomates of the American Board of Forensic Anthropology as well as other forensic anthropologists are listed on the pages immediately following this article.

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NARROW MEDULLAE IN ANIMAL HAIR

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It is universally recognized that the medullae of human hair, when present, are narrow. Animal hairs, on the other hand, typically present wide medullae; the medullary index, that is, the ratio of the diameter of the medulla to the diameter of the entire hair, is frequently greatly in excess of 0.30 in the hair of animals. The medullary index, therefore, presents one aspect of the determination of whether an evidence hair is of human or animal origin. Niyogi (1962), in a review of the forensic examination of hair evidence, states, ". . . with rare exception, the medullary index of hair of non-human animals is above 0.50."

We do not mean to suggest that the medullary index is the *only* aspect, or necessarily the most important aspect of the determination of whether a hair is of human or animal origin; as will be discussed, the appearance of the cuticle and the variability of diameter and pigmentation must also be factored into that decision. Nevertheless, the medullary index is a prominent feature when the hair is viewed in a wet-mount, and factors which influence the proper interpretation of this feature should therefore be understood to the extent possible.

There are indeed exceptions, as Niyogi hints, to the general rule that animal hairs have wide medullae. However, a listing of these exceptions does not appear in the forensic literature, or, as near as the present authors are able to determine, anywhere else. The issue addressed here is which animals may possess hair with a medullary index of 0.20 or lower, that is, which specific animals have hair which could overlap human hair with respect to medullary index. Compendia of photographs and drawings of animal hair (Glaister 1931; Wildman 1954; Appleyard 1960; Hausman 1920; Brunner and Coman 1974; Brown 1942; Mayer 1952; Moore *et al.* 1974) were examined for this purpose, using the criterion of a medullary index of 0.20 or below. (We recognize that factors such as variations in mountant, the conscientiousness of the artist in depicting the medulla in the case of line drawings, the vagaries of sample selection of the hairs, and imprecision of measurement from photographs or drawings may influence the precise value of the medullary index, but for purposes of this discussion these factors have been disregarded; any such imprecision would almost certainly be less significant than the "between-hair" and "within-hair" variation as defined below.)

Animals with hair which in some or all specimens may show a narrow continuous or fragmented medulla, but not a narrow patterned medulla, are represented in Table 1.

We are not suggesting that the hair of all of these animals is likely to pose an equivalent threat to the recognition of an evidence hair as human, but this must be put into proper perspective. The diameter of the hair, or the variability of the diameter of the hair, or the appearance of the cuticle of the hair of these animals will provide additional grounds for their discrimination, (although the cuticle may not be particularly apparent during an initial examination of the hair in a wet-mount). Secondly is the issue of the likelihood of encountering certain animals. Dog hair or cow hair may be commonly encountered. Mohair or alpaca will be much less frequently seen as evidence materials, but it would scarcely strain credulity to encounter these hairs. On the other hand, it is unlikely that the hair of the agouta, or the spiny anteater, has ever been encountered as evidence, at least in the United States. Thirdly, the medullae of animal hairs are much more variable than in human hair. This variability is of both a "between-hair" and "within-hair" type. An example of the "between-hair" type is sheep hair, that is, wool. The overwhelming majority of wool fibers examined will not show any apparent medulla. On those occasions when a medulla is encountered, however, it will be narrow, certainly within the range exhibited by human hair. Another example of "between-hair" variation is dog hair. Although the typical dog hair has a medullary index over

Table 1. Animals with a Narrow Continuous or Fragmented Medulla

Common Name	Genus and Species
Beaver	*(Castor canadensis)*
Angora goat (mohair)	*(Capra hircus aegagrus)*
Bear	*(Ursus sp.*)*
Pig	*(Sus scrofa)*
Sheep (wool)	*(Ovis aries)*
Cow, ox	*(Bos taurus)*
Flying fox	*(Pteropus poliocephalus)*
Indian goat	*(Capra sp.)*
Llama	*(Lama glama)*
Vicuna	*(Vicugna vicugna)*
Alpaca	*(Lama pacos)*
Otter	*(Lutra canadensis)*
Sea otter	*(Enhydra lutris)*
Bison	*(Bison bison)*
Fur seal	*(Callorhinus ursinus)*
Hair seal	*(Otaria jubata)*
Arctic fox	*(Alopex lagopus)*
Badger	*(Taxidea taxus)*
Hog-nosed skunk	*(Conepatus sp.)*
Striped skunk	*(Mephitis mephitis)*
Spiny anteater	*(Tachyglossus hystrix)*
Agouta (Note: This is not the Agouti, *Dasyprocta variegata*)	*(Solenodon paradoxus* also *Hispaniolan solenodon)*
Red kangaroo	*(Macropus rufus)*
Dog	*(Canis familiaris)*
Simian primates	(Various sp. including *Pan, Gorilla, Simia, Ateles* and other monkeys)

* Indicates species.

0.30, numerous individual specimens have been reported in the range of 0.15 to 0.20 (Kind 1965). An example of the "within-hair" type of variability is the otter (*Lutra*). The medullary index of the otter may be as great as 0.16 (still within the range exhibited by human hair), but may taper down to nothing on the same hair.

It is our position that good professional practice calls for the analyst to be aware of which specific animals have been reported as having a narrow medulla in at least some specimens. For example, if an analyst is conducting an examination of what may well be a mixture of human and dog hairs, then it would be well for that analyst to recognize that some dog hairs may have medullary index below 0.20. The list presented here should serve the purpose of enunciating which specific animals have been reported to have narrow medullae.

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FEATURE ARTICLE

A REVIEW OF THE FBI LABORATORY'S GUNSHOT PRIMER RESIDUE PROGRAM

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INTRODUCTION

The development of a method for the identification of gunshot residue (GSR) on the hands of a suspected shooter has been a top priority of forensic chemists for many years. Law enforcement officers and prosecutors have good reason to believe that placing the "smoking gun" in the hands of a suspected shooter by means of an incontrovertible scientific test would provide the trier of fact with a significant element in the proof required for a conviction. From a cursory study of the history of GSR tests, it is clear that such a scientific test does not exist (FBI Law Enforcement Bulletin 1935, 1940; Harrison and Gilroy 1959; Ruch *et al.* 1964; Cowan *et al.* 1973).

The tests that are in use in forensic laboratories today are either quantitative tests for chemical elements in ammunition primer mixtures or a test which specifically identifies primer residue particles by scanning electron microscopy and X-ray analysis (Wolten *et al.* 1977). None of these tests addresses the issue of how the primer residue is deposited on the hands. Nevertheless, the GSR tests are still valuable provided their limitations are understood.

Specimens taken from the hands of suspected shooters and submitted to the FBI Laboratory are analyzed by neutron activation analysis (NAA) for the elements antimony and barium. These elements are components of most primer mixtures and can be deposited on the hands when a firearm is discharged. In the early 1960s, the group at Gulf General Atomic (San Diego, CA) demonstrated that NAA was an excellent method for measuring these elements accurately over the wide concentration range found on the hands of nonshooters and shooters. These amounts typically vary from a few nanograms to several micrograms (Ruch *et al.* 1964). Their work showed that in many situations there was an increase in the amounts of antimony and barium on the back of the hand when a firearm was discharged compared to the amounts of these elements normally on the hands (Schlesinger *et al.* 1970). Based on this introductory work, the availability of a research nuclear reactor in the Washington, D. C. area and our own considerable experience, NAA has been the analytical method of choice for the examination of GSR samples for antimony and barium since the inception of the FBI Laboratory's GSR program in the late 1960s. This method is used despite the availability of the ostensibly less costly flameless atomic absorption spectrophotometry (FAAS) method used by many crime laboratories for GSR analysis. In our view, the analytical reliability of the NAA method for quantifying antimony and barium over a wide range of concentrations, coupled with the ability to process a high volume of samples through the use of a computer-controlled sample changer and automatic data reduction, make the FBI Laboratory's GSR program a cost-effective one.

SCIENTIFIC PRINCIPLE

The basis for the NAA method is to produce radioisotopes in a material by bombarding the material with neutrons. The stable isotopes of some of the elements in the material are transformed into radioisotopes. Many of these radioisotopes decay with the emission of gamma rays. The energy of the gamma rays and the rate of radioactive decay (half-life) are used to identify the radioisotopes of interest produced in the material. The intensity of the gamma rays of a specific energy is a direct measure of the concentration of an element in a material. In the case of the analysis of GSR samples for antimony and barium, the radioisotopes measured are 83 minute ^{139}Ba (166 keV photopeak) and 67.2 hour ^{122}Sb (564 keV photopeak).

ANALYTICAL PROCEDURE

The FBI Laboratory examines cotton swabs submitted by Federal, state and local law enforcement agencies in criminal matters as well as swabs from test firings and handblank projects. Generally, these swabs are of the cotton applicator type which have been moistened with a few drops of 5 percent nitric acid and applied to the hand. Each hand must be swabbed, and moistened swabs which have not been applied to any surface must also be provided as a materials blank. After a microscopic examination to determine the condition and degree of utilization of the swabs, they are removed from their sticks and packaged in labeled polyethylene bags. These bags are loaded into an irradiation container called a rabbit. The rabbit holds swabs from approximately ten persons (right hand, left hand, blank) and three vials of liquid standards, each vial containing enough solution to provide 1 ug barium and 0.1 ug antimony in 100 ul. The swabs and standards are irradiated for 1.5 minutes at a thermal neutron flux of approximately 10^{14} n/cm^2/sec in the National Bureau of Standards Reactor located in Gaithersburg, Md.

A post irradiation chemical separation is performed for two reasons. One is to remove some of the nonpertinent radioisotopes formed during the irradiation thereby reducing the total radioactivity of each sample. The second is to prepare a reproducible sample configuration to present to the radiation detector. (Even though antimony and barium can often be measured without a chemical separation, the condition and shape of the swabs make quantitation unreliable.)

CHEMICAL SEPARATION

The irradiated swabs from each sample are placed in a 100 ml disposable polyethylene beaker. A carrier solution (80° C, 25 ml) is added to each beaker. This solution contains 20 mg of barium as barium nitrate and 20 mg of antimony as antimony potassium tartrate in 3N hydrochloric acid. The cotton is mechanically dispersed, allowed to leach for at least 5 minutes to permit isotopic exchange, and then filtered on Whatman #4 paper. The filtrate is collected in a second disposable beaker. After washing, the final volume is approximately 70 ml.

Sodium sulfate (10 percent, 5 ml) is added to the filtrate to precipitate barium as barium sulfate. At least 5 minutes are required for nearly complete precipitation of the barium sulfate. Sodium sulfide (10 percent, 5 ml) is then added to precipitate antimony as antimony sulfide. Nearly complete formation of this precipitate also requires about 5 minutes. The mixture of precipitates is filtered on 47 mm 0.22 um porosity Millipore filter paper (Figure 1). The filter paper is placed in a labeled 47 mm disposable petri dish for automatic gamma counting.

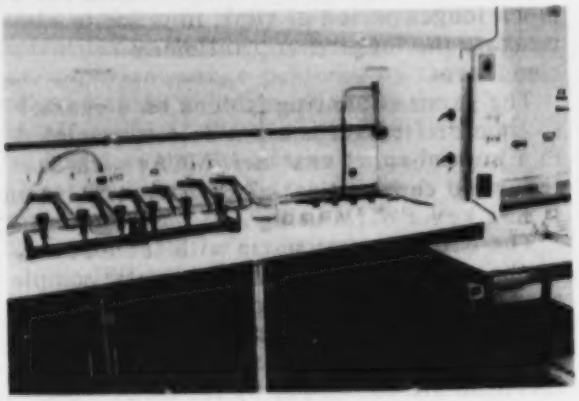

FIGURE 1. Manifold setup for filtration of antimony and barium precipitates.

Chemical yields for the antimony and barium in solution as determined using ^{125}Sb and ^{133}Ba radioactive tracers approach 100 percent. It is pointed out that antimony in some swabs does not completely exchange with the carrier. This has been determined by performing gamma counting on the swab materials after the separation procedure. (Generally, the antimony retained in the swabs does not exceed 10 percent of the total.)

The three standards are processed the same way except that the first filtration is eliminated.

GAMMA COUNTING AND DETERMINATION OF ANTIMONY AND BARIUM CONCENTRATIONS

When analyzing numerous samples, the time spent acquiring a spectrum for each sample is limited by the half-life of the radioisotope being measured. Acquiring a spectrum, a process called "counting," for too brief a period will yield insufficient data for a meaningful analysis. Allowing too much time for each sample will result in the loss of data from the short-lived radioisotopes in the last samples to be counted. Since barium decays much more rapidly than antimony, the samples are counted twice. In the first count, performed to determine the mass of barium in the samples, the counting time for each is typically less than 2 minutes. After the barium results are printed, the samples are counted again for a much longer period of time, in order to measure the longer-lived antimony component.

The gamma counting is done on a coaxial lithium-drifted germanium detector coupled to a multichannel analyzer (MCA) with data reduction capabilities. The system resolution is 1.95 keV FWHM using 1.33 MeV photons.

The barium count starts with the loading of the petri dishes onto an automatic sample changer (Figure 2). From this point on, the manipulation of each sample and the acquisition, storage and analysis of each spectrum are controlled by the MCA. The MCA begins the count by causing the sample changer to move the first sample into a position directly over the detector. The MCA reads information identifying the sample and its irradiation and counting parameters from a hard disk. This information is typically entered on the MCA keyboard prior to the chemical processing of the swabs (Figure 3). The MCA then acquires a spectrum and signals the sample changer to remove the current sample and bring in the next. The spectrum and its associated parameters are written out to the disk. This cycle is repeated until all samples have been counted.

When the gamma counting phase of the barium analysis is completed, the three standard spectra are recalled from the disk

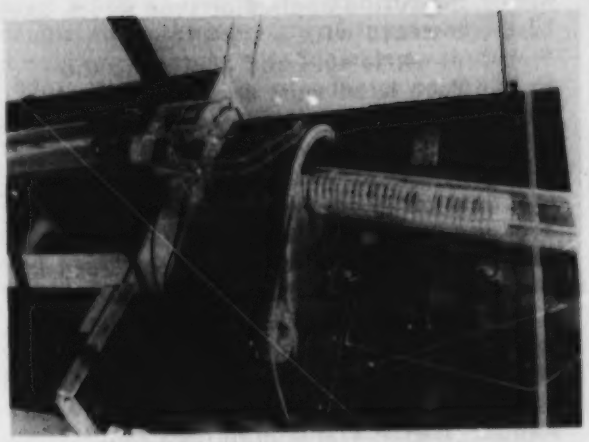

FIGURE 2. Sample changer loaded with petri dishes.

and the average activity at reactor discharge for 1 ug of barium is determined. This average activity is used to determine the micrograms of barium in each sample using the comparator method (Kruger 1971). The activity at reactor discharge is automatically calculated in each sample and compared to the average activity in the standards to determine the amount of barium in the sample. A computer printout, which contains sufficient information to manually determine this automatically calculated barium quantity, is produced for each sample (Figure 4). This "self-contained" printout is useful for inspection and review by the analyst prior to interpreting the meaning of the results and also serves as a permanent record of the analysis. As pointed out, the antimony results are obtained after reloading the sample changer and initiating the antimony counting and calculating routine (Figure 5).

An important requirement for the computer program used in the GSR analysis is that it make available the data points and the irradiation and counting parameters used to determine the antimony and barium concentrations. This is particularly evident

FIGURE 3. Multichannel analyzer and terminal.

in the peak integration routine. This routine does not determine if an actual photopeak is present. Instead, a region of interest is defined by calibrating the MCA carefully so that the photopeak of interest is present in its appropriate region. If there is no photopeak in a specific sample (this often happens for antimony, especially in the materials blank sample), the MCA will still calculate a value. Based on an inspection of the region on the printout and our experience as to the limit of detection for antimony and barium under the conditions of the analysis (approximately 20 ng for barium and 5 ng for antimony depending on presence or absence of contaminants and counting conditions), it is readily apparent when this automatically determined value is not meaningful. Some of the peak integration terms which appear in Figures 4 and 5 are defined in Figure 6.

INTERPRETATION OF DATA AND DISCUSSION

The FBI Laboratory examines GSR samples from the hands of approximately 2000 persons each year. This requires the application of batch processing methods, automatic gamma counting and automatic data reduction. However, accurate quantitative data are only one factor, albeit an important one, considered by the analyst when making a judgment about the significance of the quantities of antimony and barium detected in an actual case. Other factors include the analyst's training and experience in GSR analysis and verifiable case information.

The FBI analyst has personally participated in activities which generate data from test firings and handblanks. Over 400 firearms have been test fired in the FBI Laboratory. Many of these firearms have been fired several times to determine the effect of factors such as environment, brand of ammunition, and intervening objects have on the deposition of GSR on the hands. In a majority of these test firings the range for barium is from 0.4 ug to 5.0 ug and for antimony 0.04 ug to 2.5 ug. Hundreds of handblanks have been collected and analyzed to determine amounts of antimony and barium which can be found on the hands of nonshooters.

The analyst should have information concerning the shooting and the swabbing of the suspected gunman; for instance, the type and caliber of firearm involved, the brand of ammunition, the number of shots, and the elapsed time between the shooting and the swabbing. Often, test firing the actual

FBI LABORATORY WASHINGTON, D. C.
GUNSHOT RESIDUE ANALYSIS
3/29/85 946:32

Q1 50305065 LK

ACTIVATION END: 3/27/85 10 3:00 RT-3 3 MIN.
ACQUISITION START: 3/27/85 1222:25 GELI 15A
PRESET TIME: 96 SEC
ELAPSED REAL TIME: 97 SEC
ELAPSED LIVE TIME: 96 SEC
CALIBRATION DATE: 3/27/85
KEV/CHNL: .500
OFFSET: 0.000

297	31	30	30	28	27	21	23
304	30	32	33	22	25	30	38
311	27	34	25	27	23	31	20
318	25	26	36	19	33	32	36
325	31	38	27	33	41	40	132
332	385	331	109	34	28	18	20
339	20	18	29	33	23	24	18
346	20	28	16	25	32	30	26
353	20	25	22	29	37	28	26
360	26	22	19	34	21	30	25

MICROGRAMS BARIUM .896

% RSD COUNTING 3 9

CNTS/UG BARIUM/MIN. 1916
CENTROID CHANNEL 332
HALF-LIFE BA-139 83 MIN
BACKGROUND SPACING 20
BACKGROUND CHANNELS 10
PEAK CHANNELS 5

FIGURE 4. Computer printout of barium analysis.

FBI LABORATORY WASHINGTON, D. C.
GUNSHOT RESIDUE ANALYSIS
3/29/85 10 0:26

Q1 50305065 LK

ACTIVATION END: 3/27/85 10 3:00 RT-3 3 MIN.
ACQUISITION START: 3/27/85 1516:21 GELI 15A
PRESET TIME: 900 SEC
ELAPSED REAL TIME: 911 SEC
ELAPSED LIVE TIME: 900 SEC
CALIBRATION DATE: 3/27/85
KEV/CHNL: .500
OFFSET: 0.000

1093	24	37	37	42	35	33	36
1100	31	29	35	35	33	39	49
1107	106	196	206	145	60	41	31
1114	32	46	44	52	51	40	37
1121	35	29	43	40	57	146	433
1128	678	516	194	74	34	21	25
1135	35	41	35	28	25	52	40
1142	41	34	39	34	48	36	29
1149	49	25	36	30	36	30	41
1156	30	32	38	28	42	34	47

MICROGRAMS ANTIMONY 193

% RSD COUNTING 2.5

CNTS/UG ANTIMONY/MIN. 677
CENTROID CHANNEL 1128
HALF-LIFE SB-122 4032 MIN.
BACKGROUND SPACING 30
BACKGROUND CHANNELS 10
PEAK CHANNELS 7

FIGURE 5. Computer printout of antimony analysis.

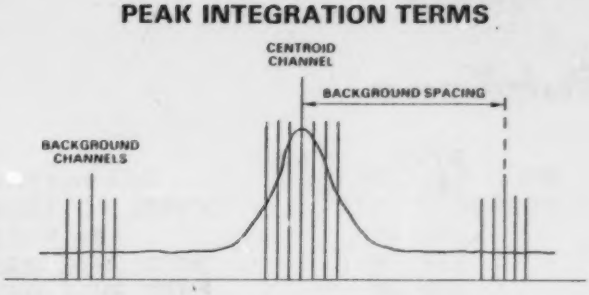
PEAK INTEGRATION TERMS
CENTROID CHANNEL
BACKGROUND SPACING
BACKGROUND CHANNELS
CENTROID CHANNEL: Channel around which maximum peak area is determined. Channel entered or stated in program ± 2 channels
BACKGROUND CHANNELS: Sum of channels on both sides of peak

FIGURE 6. Definition of terms used in peak integration routine.

firearm involved in the case is very valuable.

The analyst must finally decide if the amounts of antimony and barium measured in the case under consideration can be associated with the discharge of a firearm or are such that no association can be made. If the analyst associates the antimony and barium with the discharge of a firearm, the opinion in most cases will be that the amounts of antimony and barium are typical of the amounts found on the hands of a person who has discharged a firearm or had his hands in close proximity to a discharging firearm. This latter clause is necessary, in our view, because it is possible to get GSR on the hands if one is near a discharging firearm held by another person. For instance, a struggle for a firearm or a shot at close range by an assailant can deposit GSR on the hands of the victim. In suicide investigations, the FBI Laboratory report generally points out that there is a possibility that the GSR could have been deposited if the victim was shot at close range by another person as well as through a self-inflicted situation.

If the amounts of antimony and barium cannot be associated with the discharge of a firearm, it is so reported; however, an explanation is added which advises the reader that this does not preclude the possibility that the person could have discharged a firearm and no GSR was deposited on the hand or that this residue, if deposited on the hand, was removed by washing or wiping before the specimens were obtained.

The problem of the inconclusive examination is a difficult one. Among the possibilities for the absence of significant amounts of antimony or barium on the hands are that the person did not discharge a firearm, the firearm did not deposit GSR under the conditions of the shooting incident, the deposited GSR was removed by some activity prior to the swabbing, the swabbing was inadequate, or the chemical analysis was faulty (Kilty 1975). Of all these possibilities or combinations of them, only the last one is under the control of the analyst. It is not possible for the analyst to assign relative probabilities of occurrence for these factors; however, expert testimony is sometimes required so that the trier of fact will have available information concerning them.

The determination that there are GSR particles or chemical elements that are present in GSR on the hands does not prove that a person held and discharged a firearm. Nevertheless, it is still a valuable one. It at least places the person in an environment of GSR and can be a significant investigative aid in a shooting investigation.

ACKNOWLEDGMENT

The author gratefully acknowledges the contributions of the FBI employees who have participated in the evolution of the FBI Laboratory's GSR program.

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REGIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

The Northwestern Association of Forensic Scientists (NWAF) will hold their Spring 1986 Meeting at the Inn of the Seventh Mountain in Bend, Oregon from April 29 - May 2, 1986. Among the activities planned are a technical paper session, business meeting and a tour of the Nossler Bullet Factory. In addition, a 3-hour program on automatic weapons is scheduled. This program will be presented by the Bureau of Alcohol, Tobacco and Firearms. The Oregon State Police Crime Laboratory's Firearms Examination Section will conduct a workshop. Also, a member of the FBI Laboratory will present a paper dealing with the use of mass spectroscopy.

For further information contact Michael A. Howard, Oregon State Police Crime Laboratory, 375 N.E. Franklin Street, Bend, Oregon 97701 (telephone: 503-388-6150).

The California Association of Criminalists (CAC) will hold their Spring 1986 Seminar at the Hilton Hotel in Concord, California from May 15-17, 1986. This seminar will be hosted by the Contra Costa County Sheriff's Office Criminalistics Laboratory. Among the activities planned is a workshop entitled "Interpretation of Statistics in Forensic Literature." This workshop will emphasize forensic problems and applications.

For further information contact Kathy Holmes, Contra Costa Sheriff-Coroner, 729 Castro Street, Martinez, California 94553 (telephone: 415-372-2962).

A combined meeting of the Southern Association of Forensic Scientists (SAFS), the Southwestern Association of Forensic Scientists (SWAFS), the Mid-Atlantic Association of Forensic Scientists (MAAFS), the Midwestern Association of Forensic Scientists (MAFS), and the Northeastern Association of Forensic Scientists (NEAFS) will be held at the Radison Hotel in Lexington, Kentucky from May 26-31, 1986.

Among the planned activities are workshops, general sessions, specialized sessions and organized tours.

The MAFS Training and Education Committee, in cooperation with the Occupational Health and Safety Administration Training Institute, is sponsoring the Laboratory Health and Safety Workshop. The workshop will consist of discussions on laboratory safety including accident causation, hazard analysis and control, biohazards, laboratory wastes, electrical hazards, ventilation, compressed gasses, flammable liquids, chemical labeling and storage, health hazards and emergency procedures.

The MWAFS is sponsoring the Analytical Infrared Spectroscopy: Techniques, Applications, Computer Methods Workshop. The workshop will consist of a discussion of infrared instruments and their operation. Sample handling techniques for obtaining spectra of a wide variety of solid, liquid and gaseous samples will be presented. Topics such as reflectance methods (specular, diffuse and internal), quantitative analysis and microsampling will be examined, with a view to providing practical problem-solving skills. This workshop is a two-day course and requires a fee of $125.

The MAFS Training and Education Committee is sponsoring the Computer Workshop. The workshop will consist of a presentation of terms and definitions, a description of computer components and how they function, a presentation of how the computer communicates with peripherals, and a discussion of what specifications and options to request when purchasing a computer. The workshop will also feature a number of computer and instrument companies exhibiting their computers and software, and forensic scientists demonstrating how computers are used in their laboratories to perform various functions.

The Introduction to Human Immunoglobulin Allotyping in Forensic Serology Workshop will introduce the procedures involved in testing serum, bloodstains, seminal stains and other body fluids for immunoglobulin allotypes (Gm and Km). Information on the body distribution, nomenclature, inheritance, phenotype frequencies, helpful hints, problem solving and examples from actual cases will also be presented. There is a fee of $50 for this workshop.

For further information contact Mike Alfultis, Loraine County Crime Laboratory, 1005 North Abbe Road, Elyria, Ohio 44035 (telephone: 216-233-7244).

The Southern Association of Forensic Scientists (SAFS) will hold their 20th Anniversary Fall Symposium at the Auburn Conference Center in Auburn, Alabama from September 10-13, 1986.

The Program Chairman for the symposium is Ronald Singer. He can be contacted at the Jefferson Parish Crime Laboratory, 3300 Metairie Road, Metairie, Louisiana 70001 (telephone: 504-832-2320).

For further information contact Carlos L. Raben, Alabama Department of Forensic Sciences, P.O. Box 231, Auburn, Alabama 36831-0231 (telephone: 205-889-70001).

The Midwestern Association of Forensic Scientists will hold their 50th Anniversary Meeting in Springfield, Illinois from October 8-10, 1986.

The Program Chairman for the meeting is Ted Elzerman. He can be contacted at the Illinois Department of State Police, Bureau of Forensic Sciences, 726 South College Street, Springfield, Illinois 62707 (telephone: 217-782-4649 or 217-782-4975).

For further information contact John Klosterman at the address listed above.

The Northwest Association of Forensic Scientists (NWAFS) will hold their Fall 1986 Meeting at the Red Lion Riverside in Boise, Idaho from October 8-10, 1986.

For further information contact Pam Server, Bureau of Laboratories, 2220 Old Penitentiary Road, Boise, Idaho 83712 (telephone: 208-334-2231).

The Mid-Atlantic Association of Forensic Scientists will hold their Fall 1986 Meeting at the Carousel in Ocean City, Maryland from October 23-24, 1986.

For further information contact Amy Wong, Northern Regional Forensic Laboratory, P.O. Box 486, Merrifield, Virginia 22116 (telephone: 703-573-8636).

The Northeastern Association of Forensic Scientists (NEAFS) will hold their 12th Annual Meeting in Peabody, Massachusetts from October 24-25, 1986.

For further information contact Dr. William Adams, Department of Chemistry/Physics, Salem State College, Salem, Massachusetts 01970 (telephone: 617-745-0556, ext. 2526).

The Midwestern Association of Forensic Scientists (MWAFS) will hold their Fall 1987 Meeting on Mackinac Island, Michigan from October 6-9, 1987. This meeting will be hosted by the Michigan State Police Forensic Science Division.

For further information contact Richard E. Bisbing, Michigan State Police Laboratory, 6296 Dixie Highway, P.O. Box H, Bridgeport, Michigan 48722 (telephone: 517-777-9300).

NATIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

The Association of Firearm and Tool Mark Examiners (AFTE) will hold their 17th Annual Seminar in Baltimore, Maryland from April 28-May 2, 1986. This seminar will be hosted by the Baltimore Police Department.

Among the scheduled activities are presentations from representatives of the Drug Enforcement Administration, the Federal Bureau of Investigation, John Hopkins Hospital, the National Bureau of Standards and the National Rifle Association among others. Also scheduled are tours of the Baltimore Police Crime Lab and the Aberdeen Proving Grounds.

For further information contact Joseph A. Reitz, 1986 AFTE Chairman, Baltimore Police Department, 601 E. Fayette Street, Baltimore, Maryland 21202.

INTERNATIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

The Federal Bureau of Investigation will host a symposium entitled, "An International Symposium on Digital Image Processing for Forensic Applications." The symposium is scheduled for June 15-20, 1986 at the FBI Academy in Quantico, Virginia. The symposium will be devoted to technical papers on techniques and methodology in examining forensic images.

For further information contact SA Michael G. Noblett, Laboratory Division, J. Edgar Hoover FBI Building, 10th and Pennsylvania Avenue, N.W., Washington, D.C. 20535 (telephone: 202-324-4427).

The Federal Bureau of Investigation will host a symposium entitled, "An International Symposium on Forensic Immunology." The symposium is scheduled for June 23-26, 1986 at the FBI Academy in Quantico, Virginia. The symposium will provide a forum for the discussion of techniques and issues relevant to the immunological analysis of body fluid evidence. Plenary sessions will be devoted to lectures by prominent scientists on forensic immunological topics such as the immune response, antibody-antigen interactions, immunofixation methods, monoclonal antibodies, ELISA, individualization and quality assurance. Afternoon sessions will be devoted to short papers, poster sessions and/or discussions of pertinent research, training, scientific data and testimony topics.

For further information contact SA James J. Kearney, Symposium Coordinator, FSRTC, FBI Academy, Quantico, Virginia 22135 (telephone: 703-640-6131, ext. 3307).

The Japanese Society of Electron Microscopy and the Science Council of Japan will host the XIth International Congress on Electron Microscopy (XI ICEM). The congress is scheduled for August 31-September 7,1986 in the Okazaki area of the city of Kyoto. The congress will be devoted to plenary sessions, symposia, workshops, public lectures and poster and/or oral presentations of contributed papers. Emphasis will be placed in the poster sessions. Symposia and workshops on recent topics in the technology and application of electron microscopy are among the scheduled activities. The official language of the XI ICEM is English.

For information contact Professor Kazuo Ogawa, Chairman, Executive Committee of the XI ICEM, Department of Anatomy, Faculty of Medicine, Kyoto University, Konoecho, Yoshida, Sakyoku, Kyoto 606, Japan (telephone: 075-751-7727; telex: 05422693 LIBKYU J).

The International Committee on Alcohol, Drugs and Traffic Safety (ICADTS) announces the 10th International Conference on Alcohol, Drugs and Traffic Safety to be held at the RAI-Congress Centre in Amsterdam, Netherlands from September 9-12, 1986.

The purpose of this conference will be to present the state of the art on Alcohol, Drugs and Traffic Safety. Through the years attention has shifted from alcohol to alcohol and other drugs and from contributions by the medical and legal professions to other professions involved in safety research. These changes will be emphasized in this years program. Special attention will be given to the role of drugs other than alcohol and on the application of available scientific knowledge to safety actions.

The provisional program includes sections on: experimental studies on the detrimental effects of alcohol and other drugs, epidemiology general preventive actions, special preventive actions, systematic analysis and evaluation of potential counteractions. Keynote speakers will be invited to present state of the art reviews for each part of the program. Papers of other speakers are expected to provide new empirical evidence in the fields of interest. Contributions of a technical or specialist nature will be concentrated in workshops or other special events such as poster sessions. Exhibition facilities will be provided.

The Chairman for the conference is C. L. A. Heijster.

For further information contact Symposium Secretariat, QLT Convention Services,

Keizersgracht 792, 1017 EC Amsterdam, Netherlands (telephone: 020-261372; Telex: 31578 inter nl. att. QLT)

The Canadian Society of Forensic Science will hold their 33rd Annual Meeting at the Sheraton-Brock Hotel in Niagara Falls, Ontario from September 15-18, 1986.

The theme of this year's meeting is "Environmental Risks and Forensic Science." This theme will be covered from a medical, legal, toxicological and environmental perspective.

The meeting will be devoted to plenary sessions, workshops and scientific sessions. A plenary session on aircraft disasters is scheduled. A film entitled "Operation Overdue" which deals with the crash of the New Zealand Airline DC-10 into Mount Erebus will be shown. Also within this plenary session will be a presentation by an on-site investigator of the Air India 747 crash into the North Atlantic. Other presentations include Mass Disaster - Computerization, Impression and Casting Material Selection for Bite Impressions on Non-Living Subjects and Armementarium for use in Forensic Odontology. Planned workshops include Gm-Km Blood Typing, Fiber Textile Identification and Manufacture, and Interpretations and Influence of Drugs on Driving.

Scientific papers are requested for presentation at this meeting. Titles and abstracts should be forwarded by July 15, 1986 to the Canadian Society of Forensic Science, 2660 Southvale Crescent, Suite 215, Ottawa, Ontario, Canada K1B 4W5.

For further information, address inquiries to Dr. George E. Burgman, President, or Dr. Ray Prime, Program Coordinator.

The International Association of Forensic Toxicologists will hold their 8th Triennial Meeting in Banff, Alberta, Canada in July 1987. Among the planned activities is a special session on Postmortem Changes Affecting Toxicology.

Confirmed reservations are required. The deadline for making reservations is January 1, 1987.

For further information contact N. Dunnett, Home Office Forensic Science Laboratory, Aldermason, Berkshire, RG7 4PN, UK.

The International Association of Forensic Sciences will hold their 11th Meeting at the Hotel Vancouver in Vancouver, British Columbia, Canada from August 2-7, 1987. The meeting will be structured around plenary sessions, short paper sessions, technical exhibits, poster sessions, and an arts and crafts exhibition. Special presentations by the International Academy of Legal Medicine and Social Medicine, and the International Study Group on National Unexpected Deaths are scheduled for the meeting. Plenary sessions include Collection and Presentation of Evidence, Conduct of a Criminal Trial and Sentencing the Offender.

Abstracts should be forwarded by December 31, 1986 to the International Association of Forensic Sciences, Suite 801, 750 Jervis Street, Vancouver, British Columbia, Canada V6E 2A9 (telephone: 604-681-5226).

INSTRUCTIONS FOR SUBMITTING ARTICLES

In order to facilitate rapid publication, submissions should conform to the following:

1. Manuscripts should be typed, double-spaced, on 8½" × 11" paper. Submit three copies of the manuscript (one of which must be the original with glossy photographs).

2. Tables should be as simple as possible. Each table should be typed on a separate sheet of paper and should include a heading.

3. Graphs and diagrams should be submitted as sharp photographs on white glossy paper.

4. References in the body of the paper should refer to the author's (authors') name(s) and the date of publication. For example:
   According to Doe and Smith (1972) . . .

   . . . has been discussed in the literature (Doe and Smith 1972; Weinburger et al. 1984; Jones 1981).

5. References at the end of the paper should appear in alphabetical order. Journal references should include the author's (authors') name(s), date of publication, title of the article, journal, volume number, and the beginning and ending pages of the article. Please follow the format below.

   Davis, H. E. and Jones, B. A. (1978). Seasonal variations in plasma hormones, Biol. Reprod. 88:271-273.

   List articles or chapters within a book as follows:

   deHaseth, J. A. (1982). Fourier transform infrared spectrometry. In: Fourier, Hadamard and Hilbert Transformations in Chemistry, (Marshall, A. G., ed.) Plenum Press, New York, pp. 387-420.

6. Technical papers should be written in an Introduction, Materials and Methods, and Results and Discussion format.

7. When reference is made to a particular product, state the manufacturer of the product and the city and state of the manufacturer's headquarters. For example:

   Isotactic PS (Dow Chemical, Midland, MI) . . .

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Crime Laboratory Digest

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Fire Investigation
Part I: Scene Investigation

J 1.14/18:

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Inclusion of an article in the Crime Laboratory Digest in no way represents an endorsement or recommendation of any part of that article by the Federal Government, the Department of Justice or the FBI. Contributing authors assume total responsibility for the contents and accuracy of their submission. Questions or requests concerning an article should be directed to the contributing agency.

All submissions are subject to editorial review in accordance with the editorial policy established by the FBI Laboratory and ASCLD. The editorial staff of the Crime Laboratory Digest reserves the right to edit all articles for style, grammar and punctuation. Comments and letters to the editor are encouraged and will be published when appropriate and as space permits. These should be forwarded to:

Crime Laboratory Digest - Editor
FSRTC, FBI Academy
Quantico, Virginia 22135

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ISSN NO. 0743-1872

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ON THE COVER

The cover, prepared by the Special Projects Section of the FBI Laboratory, depicts photographs taken during the investigation of a fire scene.

MESSAGE FROM THE ASSISTANT DIRECTOR IN CHARGE OF THE FBI LABORATORY

This past month, the FBI Laboratory celebrated the fifth anniversary of the opening of the Forensic Science Research and Training Center (FSRTC) at Quantico, Virginia. Coincidentally, the American Society of Crime Laboratory Directors (ASCLD), who assist with some of the FSRTC programs, were having their spring Board of Directors meeting and were able to share in the celebration. Our goals for this new facility were primarily twofold. One, through an enhanced research effort, was to provide a service to the law enforcement community by developing new techniques to support both FBI operations and the law enforcement community in the examination of evidence. The second goal was to provide both technical and nontechnical training, thus bringing these newest research developments to the forensic community.

On the research front, we have hired scientists in a number of disciplines including biology, chemistry and materials analysis to develop new analytical methods for examining trace evidence such as body fluid stains, plastics, automotive paints, soils and drugs. When these new methods are developed, we make every effort to inform the forensic community by publishing the research results in scientific literature, including the Crime Laboratory Digest. The training programs now offered at this new facility have expanded and enhanced our curriculum. The new facility, by providing more training space, permits the simultaneous instruction of various technical courses while using the latest scientific instruments. During the 5-year period, we have provided training to more than 5,000 law enforcement and forensic science personnel in over 25 different technical courses including serology, chromatography and specialized techniques in firearms identification.

One program the FSRTC has hosted which has had a great impact on the forensic community is the international symposia on different technical forensic topics. The symposia have brought together the research and training efforts of the FBI as well as other law enforcement agencies, academia and industry and focused them on specialized forensic topics. During the month of June, the FBI Laboratory hosted its eighth and ninth international symposia. An International Symposium on the Forensic Applications of Digital Image Processing was held the week of June 16-20. A total attendance of 55 individuals included representatives from the United Kingdom, Italy, Israel, Canada, New Zealand, Japan and the Federal Republic of Germany. Twenty-five plenary presentations were made emphasizing the development of new methods and technology to examine documents using digital image processing. The second symposium, the ninth in the series, was the International Symposium on Forensic Immunology, held June 23-26. This symposium featured 12 plenary presentations, 30 short papers and 2 panel discussions on various topics in forensic immunology. There were 175 individuals in attendance with representatives from 38 states and the countries of the United Kingdom, France, Italy, Japan, the Federal Republic of Germany and Canada.

Recently, I had the opportunity to attend the second International Symposium on the Analysis and Detection of Explosives which was held in Israel, June 29 - July 3. This symposium provided an update on the latest advances in explosive detection and analysis and was a follow-up to the first international symposium hosted by the FBI Laboratory in 1983 on the same topic. All of these symposia have brought together recognized experts in different specialized forensic science fields and have fostered the continued exchange of significant information on new developments in the forensic sciences.

In the future, in addition to continuing our research and training efforts, the FBI Laboratory plans to co-host two ASCLD recommended specialized symposia at the FSRTC in 1987. The first will be on latent print detection, co-hosted with the FBI Identification Division. The second will be on drug analysis, co-hosted with the Drug Enforcement Administration. The FBI Laboratory is proud to sponsor the forensic science symposium program, and with your continued support, we believe the FSRTC can provide an important service to the forensic community in the years ahead.

ROBERT S. GAST II

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In this issue of the Crime Laboratory Digest, part one of a two part review article on fire investigation is presented. The first part covers the fire scene investigation, and the second part, to appear in the January 1987 issue, will discuss laboratory analysis of fire debris. Also in this issue is an article by Allyson Simons from the Hairs and Fibers Unit of the FBI Laboratory concerning hairs found on laundered items. Tom Munson offers a practical guide for getting started with pyrolysis capillary gas chromatography. The results of a recent survey by Dr. Munson on pyrolysis capillary gas chromatography will appear in the October issue of the Crime Laboratory Digest.

At the recent American Society of Crime Laboratory Director's Board meeting held at the FBI Academy, interest was expressed in having articles published in the Crime Laboratory Digest on building a crime laboratory and managing a crime laboratory. Please contact the editor if you are interested in writing such an article. Additionally, at this most recent meeting there was an interest in providing information about employment opportunities in the forensic science community. Beginning in the October issue, we will publish current employment listings. Please forward information about relevant employment opportunities to the editor at the FSRTC, Quantico.

PROCEEDINGS OF INTERNATIONAL SYMPOSIA PUBLISHED BY THE FBI LABORATORY

Proceedings of three international symposia previously hosted by the FBI Laboratory and held at the FSRTC are available from the Government Printing Office. These are:

The Proceedings of the International Symposium on the Analysis and Detection of Explosives, stock number 027-001-00032-7, price $17.00.

The Proceedings of a Forensic Science Symposium on the Analysis of Sexual Assault Evidence, stock number 027-001-00037-8, price $9.50.

The Proceedings of the International Symposium on the Forensic Applications of Electrophoresis, stock number 027-001-00039-4, price $8.00.

To obtain copies of these publications, inquires should be directed to:

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

ERRATA

In our last issue, figure 2 on page 56 appears sideways. The figure is included in the feature article, "A Review of the FBI Laboratory's Gunshot Primer Residue Program" by John W. Kilty.

CENTRAL RESEARCH ESTABLISHMENT REPORTS

The Central Research Establishment (CRE), Home Office Forensic Science Service, Aldermaston, Reading, England, has provided the FBI Laboratory with copies of CRE Reports on completed research projects. By mutual agreement between the FBI and the CRE, these reports are available to all duly authorized law enforcement organizations in the United States. To obtain these reports, send a request from your crime laboratory director to:

Federal Bureau of Investigation
Colleen Wade, Librarian
Forensic Science Information
Resource System
Room 3589
10th and Pennsylvania, N.W.
Washington, D.C. 20535

The following CRE Reports are now available:

A Collection of Infra-Red Spectra of Paints and Fibres Obtained Using High Pressure, D. K. Laing and J. M. Home, CRE Report #372

The Detection of Trace Impurities in Soluble Food Dyes, J. R. Joyce and I. J. Humphreys, CRE Report #373

Routine Determination of Opiates and Their Metabolites in Biological Fluids by Radioimmunoassay, P. A. Mason, B. Law, K. Pocock and A. C. Moffat, CRE Report #376

An Assessment of the Use of Ultra-Violet Derivative Spectroscopy in Chemical Analysis, T. S. Bal and A. C. Moffat, CRE Report #377

A Study of Leucine Aminopeptidase as a Possible Means of Identifying Semen, M. E. Lawton and J. G. Sutton, CRE Report #378

The Use of a Vanillin-Sulphuric Acid Reagent to Distinguish Between Certain Barbiturates, H. M. Stevens, CRE Report #379

Factors Affecting Voltage Conditions in Cross-Over Electrophoresis, S. M. Fletcher and P. Dolton, CRE Report #382

Gas-Liquid Chromatographic Retention Indices of 1318 Substances of Toxicological Interest, R. E. Ardrey and A. C. Moffat, CRE Report #384

The Assessment of Commercially Available Anti-H Reagents for Forensic Purposes, B. G. Lang and G. Horscroft, CRE Report #385

Preparation of an Iodinated Barbiturate Derivative for Use in Radioimmunoassay, P. A. Mason and B. Law, CRE Report #386

Evaluation of Specific Anti-Saliva Serum, S. M. Fletcher, P. Dolton and P. H. Whitehead, CRE Report #389

Isoelectric Points (pl) of the Isoenzymes of Phosphoglucomutase, J. G. Sutton, CRE Report #453

Species Identification of Blood and Saliva Stains by Elisa Using Monoclonal Antibody, S. M. Fletcher, P. Dolton and P. W. Harris-Smith, CRE Report #457

Information on New Drug Captopril (Capoten), P. J. Gomm, A. R. Allan, T. S. Bal and M. M. Harding, CRE Report #464

Information on New Drug Lormetazepam (Noctamid), P. J. Gomm, A. R. Allan, T. S. Bal and H. D. Poole, CRE Report #465

REVIEW ARTICLE

FIRE INVESTIGATION. PART I: SCENE INVESTIGATION

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This first review article will address fire scene investigation with the objective of determining origin and cause of a fire; the second article will address laboratory techniques in fire debris analysis. These articles are not intended to constitute a course of instruction, but they should provide a review for experienced forensic investigators and a perspective for investigators new to the field. Several different courses for fire scene/arson investigators are offered by state and federal law enforcement training centers such as the Bureau of Alcohol, Tobacco, and Firearms and the Federal Bureau of Investigation. Subjects such as interviewing techniques, determination of motive, development of substantiating documentation from records searches and testifying are outside the scope of what is to be presented here.

PREPARATION

Several elements are essential to effectively investigate a fire scene:

1. Mental Attitude

The investigator needs to be suspicious, but in a controlled manner. He must realize that he is investigating a "fire" and not necessarily "arson". An objective, unbiased approach is necessary to minimize the probability of overlooking, ignoring, or discounting evidence of potential value.

2. Permission

It is necessary that the police, fire department personnel and the owner/occupant of the property understand the basis for the investigator's right and duty to be on the premises and what his duties, obligations, and limitations are. In cases where the investigator is a member of, or working through, a law enforcement agency, the legal statutes will provide permission. In the case of a private investigator working for or under the direction of an insurer, the permission is obtained as a condition of the insurance policy.

3. Equipment

In addition to comfortable work clothes and boots or shoes, the investigator needs a variety of other equipment such as a compass, tape measures, shovels, lights, etc. Many of these items will be acquired as more fire scenes are investigated and as needed. The National Bureau of Standards Fire Investigation Handbook (NBS Handbook 134) lists two pages of basic equipment. Of utmost importance is good, reliable equipment for documentation including notebooks, a tape recorder and photographic equipment. Many scenes are investigated in remote areas where valuable time can be wasted while obtaining the proper tools or trying to work without them. Fire scenes are inconvenient enough to work even when the proper equipment is available.

4. Knowledge and Training

A basic knowledge of the chemistry and physics of combustion and fires as well as construction plumbing, electrical wiring, and legal and courtroom procedure will serve the investigator well, and he should avail himself of opportunities to increase his familiarity with them. There are a number of privately taught and government sponsored fire investigation courses and seminars available which can help to develop the rudiments of investigation. However, these courses cover the subject in a cursory manner and complement rather than substitute for training with a good, experienced fire investigator. Time and effort spent gaining proficiency with photographic equipment and reporting techniques cannot be underestimated. The ultimate product of the investigator's efforts is a report which conveys his observations and conclusions along with proper supporting documentation. If he fails at this point, all the previous work, no matter how well done, is either wasted or severely limited in effect.

5. Specific Information

Prior to beginning work on the fire scene, the investigator should have information about when (time and date) the fire started, who reported it, who was there at the time, who responded to it, how long it took to control it and who else had been on the scene or investigated it. This basic information will help in determining the area of origin, what fuel and heat sources were in the structure and how the fire spread.

SCENE - ORIGIN

It is desirable for the investigator to arrive at the fire scene as soon after the incident as possible. However, many times there is a considerable delay, and frequently the scene has not been secured. These factors need to be documented, as they can be of potential significance. Upon arrival at the scene, the investigator should observe and photograph the structure as it is found (as shown in Figure 1) along with its immediate surroundings and establish the proper geographic orientation.

FIGURE 1. Exterior wall, windows and portion of roof.

Items to be noted at this time include:

1. Safety hazards such as weakened walls, roofing, chimneys, etc. The investigator will be working around these structures, and attention to safety details can help avoid an accident.

2. Utility supplies, particularly gas and electric services and loose service wiring. The fire department will usually have secured these, but the investigator should know by his own inspection that valves are turned off, meters are pulled and loose wiring is dead.

3. Documentation of construction details such as type of roof, foundation building materials, etc., areas where fire broke through the roof, windows, walls, etc. and areas where smoke vented from the structure. This can often help determine the progression of the fire.

4. Items removed from the structure during overhaul. Examination of these items may begin to establish a pattern of the kinds of things expected to be present which are or are not there and things which would not normally be expected to be present but may be there and require justification. Examination of the contents of trash cans and wastebaskets may produce potential significant evidence.

5. After the outside safety and utility checks, external examination of the structure and results of the overhaul, a walk-through of the interior is in order. The primary purposes here are to locate dangerous conditions due to weakened floors, ceilings, walls and roof, to become familiar with the layout and to assess relative damage to the various areas. The interior of the structure should be photographed showing it as it was found.

6. A dimensioned, labelled sketch of the overall structure indicating locations of doors and windows and whether they were open or closed when found, utility service supplies to the structure, the fuse or breaker box and major items such as the water heater, air conditioners, washer, and dryer. It may be convenient to check for any evidence of forced entry and to document the condition of the fuse or circuit breaker box at this time.

7. The systematic examination of the structure is begun by examining the least involved areas first and working toward the areas of greatest involvement. In theory, this process should in most cases lead to the point(s) or area(s) of the fire's origin. As an area is examined, it may be necessary to make a separate detailed sketch of it. In any event, the area should be examined, with appropriate photographs taken and descriptive comments documented with regard to:

a) Type of room, such as bedroom, kitchen, bathroom, etc. (Figures 2 and 3).

b) Items present and their condition such as furnishings, pictures and personal items including contents of drawers and closets. Sizes of clothes can be important. Note things which are there and would be expected to be there as well as things which are present but would not necessarily be expected there. Also note the absence of items which might normally be present, such as personal photographs, guns, etc.

c) Position and condition of doors and windows. Do heat damage or smoke deposits indicate whether doors or windows were open or closed at the time of the fire? Position of light switches - on or off? (Figure 4).

d) Presence of high burn, low burn, vee patterns and extent and location of smoke damage.

e) Burn patterns which might indicate pour patterns or trailers.

f) Condition of ceiling. A hot, fast fire on the floor will sometimes create an almost identical pattern on the ceiling. On some textured ceilings, smoke deposits will sometimes be heavier on ridges facing toward the direction from which smoke has come, much as the western slopes of the Rockies receive more rain than the eastern slopes from moist air moving west to east.

g) Relative char or damage to faces of studs, door facings and furniture can frequently indicate which side was exposed to the highest temperatures and may be useful in assessing progress of the fire.

h) Alligatoring or blistering of wood (note Figure 4) can sometimes be of limited value in assessing whether a fire was fast developing or smoldering. Large scales with a shiny surface might indicate a fast developing fire, although this should not be assumed since type of wood and surface treatment can alter these effects.

The checklists shown in Tables 1 and 2 can serve as a guide to items which should be considered. It should be recognized that these lists are not all inclusive and should only be used as a guide. In addition, there is a danger of being too superficial or overly concerned with checking off items on the lists. A recommended practice would be to note pertinent items during the fire scene examination for use as documentation and as a reminder to consider the other items.

FIGURE 2. Kitchen sink, counter and cabinets.

FIGURE 3. Bathroom wall, pipes and remnant of commode.

Table 1. FIRE SCENE EXAMINATION CHECKLIST

Checklist Items	Kitchen			Bathroom			Living Room			Dining Room		
		Cabinet	Cabinet		Closet	Closet			Closet			Closet
Utensils												
Pots/pans												
Appliances												
Food												
Beverages												
Cleaning materials												
Trash can												
Clock												
Furniture												
Pictures												
Windows (O/C/L)*												
Doors (O/C/L)*												
Lighswitches (On?)												
Ashtrays												
Shaving gear												
Cosmetics												
Hairdryer												
Radio												
Books/magazines												
Vacuum cleaner												
TV/stereo												
Lamps												
Carpet												
Fireplace												
Clothes												
Clothes hangers												
Shoes												
Jewelry												
Guns												
Tools												
Paint cans, etc.												
Pets												
Electrical service												
Gas service												

* Denotes O=open, C=closed, L=locked.

Table 2. FIRE SCENE EXAMINATION CHECKLIST

Checklist Items	Bedroom						Hall			Garage		Utility	
		Closet			Closet	Closet			Closet				
Utensils													
Pots/pans													
Appliances													
Food													
Beverages													
Cleaning materials													
Trash can													
Clock													
Furniture													
Pictures													
Windows (O/C/L)*													
Doors (O/C/L)*													
Lighswitches (On?)													
Ashtrays													
Shaving gear													
Cosmetics													
Hairdryer													
Radio													
Books/magazines													
Vacuum cleaner													
TV/stereo													
Lamps													
Carpet													
Fireplace													
Clothes													
Clothes hangers													
Shoes													
Jewelry													
Guns													
Tools													
Paint cans, etc.													
Pets													
Electrical service													
Gas service													

* Denotes O=open, C=closed and L=locked.

FIGURE 4. Light switch in "on" position and blistering of walls.

SCENE - CAUSE

When it is believed that the point(s) or area(s) of origin have been located, it is necessary to identify the cause of the fire. All possibilities of natural or accidental causes should be considered and must be eliminated before an incendiary cause can be fully substantiated. This must be done regardless of how obvious it may be that the fire was incendiary.

The most common natural causes of fire are lightning and spontaneous heating and ignition. For lightning to have been the cause, there must have been some history of lightning prior to the fire. There will usually be damage, sometimes but not always severe, to wiring or other conducting materials and frequently to one or more electrical appliances. Dates and times of inclement weather can be documented through the Department of Commerce, National Oceanic and Atmospheric Administration.

Spontaneous heating and ignition requires the presence of materials which are readily oxidized and confined in a location or orientation which deters dissipation of heat and which is usually close to another ignitable fuel source. Perhaps the classic example of this type of situation is cloth which has been used to wipe up turpentine or mineral spirits. The cloth fibers represent a relatively high surface area over which the combustible liquid can be distributed. If the cloth is placed in a pile in a location where heat generated by air oxidation of the turpentine is not readily dissipated, the temperature of the pile can rise. As the temperature rises the oxidation rate increases, and if there is sufficient air and fuel available, ignition can occur. Once ignition occurs, any other fuel load in the area is subject to ignition under proper conditions. Spontaneous heating and ignition requires a particular set of conditions and is not common, but it must be kept in mind as a possibility. In a similar manner, a pile of damp straw, hay or grass can ignite because of heat generated by bacterial action. A key point to remember in reference to spontaneous combustion is that it will not occur with petroleum based products alone. They may add to the fuel load after combustion but will not be the catalyst.

Accidental fires are much more likely to occur than fires started by natural causes. Among the most common accidental causes are careless flames such as matches and cigarettes, electrical origins such as circuit overloading which can result from too many or faulty appliances, poor wiring resulting from non-code installation or abraded insulation and misuse of appliances which might result in a grease fire while cooking or a fire from an iron left on and unattended (Figure 5). Other accidental fires may be the result of spillage, leakage or storage of flammable materials such as paint thinner, gasoline or charcoal lighter fluid near pilot lights or other open flames. Improper use or placement of space heaters or malfunctioning regulators on space heaters, furnaces and water heaters may also cause accidental fires.

When determining if damage was due to an accidental cause, it must be remembered that often the damage is a result of the fire rather than a cause of it. For example, a fire may destroy the insulation on electrical wires and result in damage which may be difficult or impossible to differentiate from damage which occurred prior to the fire. Examination of the immediate surroundings may shed more light on such a situation. If a series of shorted wires and wires from various circuits are found within an area

which has sustained heavy fire damage, this might be an indicator that the damage was a result rather than a cause of the fire.

If no natural or accidental cause is identified, an incendiary cause can be suspected and the examination pointed in that direction. Even though there may be evidence of trailers, pour patterns or similar suspicious findings, it is still necessary to eliminate the natural and accidental causes. Because of the damage sustained and the usually haphazard conditions which exist at many fire scenes, there frequently are misleading signs which can lead an investigator toward an incorrect conclusion if he concentrates on them to the extent that he misses or ignores other factors. It is essential to keep an open mind and be thorough, methodical and objective.

FIGURE 5. Electric skillet. Grease in skillet is possible cause of fire.

THEORY AND DOCUMENTATION

If a fire is thought to be a set fire, a theory of how it was set and its progress should be developed, substantiated and documented. This involves tracing the fire from its origin(s) and cause and explaining how the evidence observed supports the theory. The most effective documentation consists of a narrative report which includes photographs. Photographs will preserve the scene and relevant evidence regarding the cause and origin. They will also serve to illustrate important points in reports. A camera that produces negatives provides the best photographic documentation. Instant print film generally will not provide the quality needed. A 35mm camera is the ideal type of camera to use. It need not be highly sophisticated, but it should be a unit the investigator feels comfortable using. A variable lens is helpful. One that has a range of 28mm to 85mm is preferable, but if a fixed lens is chosen, one in the 50mm to 55mm range is the most useful. The flash unit is very important. Again, this need not be an expensive unit but must primarily have the power to compensate for the dark, carbonaceous material being photographed.

If debris samples are taken, they should be properly labelled, identified and sealed. The area the samples are taken from should be photographed before the samples are secured. It is good practice to not only describe where they are taken and the material they contain but to photograph each in place with identifying marks so that the reader knows exactly the area of interest. Two photographs of the debris samples should be taken; one close up to readily identify the sample and its identification marks, and a second photograph to show the sample in perspective to the overall area from which it was taken. The samples should be measured from two fixed points and so indicated on the diagram. If possible, it is best to measure and diagram the entire structure where the loss occurred. This further documents that the whole area has been inspected. Graph pads with ruled lines are most helpful when sketching the structure. When preparing the report with his theory and documentation, the investigator must consider the possibility it will be read or presented to someone that has little or no fire investigation knowledge. Therefore, the report must contain information that can be understood by the layman but still convey the expertise of the investigator.

SUMMARY

The complexity of fire investigations and the types of evidence potentially involved make it imperative that the investigator

develop and follow a methodical, logical, thorough and open-minded approach to these investigations. It is also essential for accurate and thorough documentation to be a part of the investigation. Disposition of cases frequently occurs after a substantial lapse of time, and the file is the investigator's total record - it must be complete. This article has attempted to review elements which will promote effective fire investigation.

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HAIR EVIDENCE ON LAUNDERED ITEMS

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The question sometimes arises in crime laboratories as to whether a large amount of significance should be placed on hair associations where clothing evidence to be examined has been laundered. Since the purpose of laundering is to remove dirt, lint and extraneous material, it would be logical to assume that hairs would be removed from items during laundering. A review of the forensic science literature revealed that this question concerning hair evidence has not been addressed and has only recently been addressed for fiber evidence (Robertson and Olaniyan 1986).

In a three phase study the Federal Bureau of Investigation (FBI) Laboratory examined the following issues: Do hairs occur on items that have been laundered? Can hairs be transferred from one item to another item when they are laundered together? What happens to hairs located on items when they are laundered?

MATERIALS AND METHODS

Phase I

Can hairs be found on items that have been laundered? To answer that question employees of the Hairs and Fibers Unit of the FBI Laboratory provided items of clothing from their laundry after washing and drying. Seventeen items were examined for the presence of hairs after they were machine washed and machine dried. Both private and commercial machines were used. Items included were dress shirts, sweatshirts, knit shirts and a bath towel. Laundered items were visually examined and hairs were removed in the FBI Laboratory using a "scraping" procedure (repeated strokes with the edge of a spatula to remove surface debris). Hairs were collected and examined microscopically.

Phase II

To determine whether hairs can actually transfer from one item to another during laundering (machine washing and drying), the author laundered five items from which all human hairs had been removed (Group A) with other dirty items (Group B). Before washing, hairs were removed from Group A items by picking, scraping and taping. Laundering was done by machine washing and machine drying at a self-service laundry. The Group A items included a knit turtleneck shirt, an oxford cloth dress shirt, a pair of socks and a T-shirt. These items were laundered with items from which hairs had not been removed (Group B).

Phase III

Next, the author examined what happens to hairs on items during laundering. This was accomplished by placing "seed" hairs on eight recipient items, then laundering these items with eight non-recipient items. Seed hairs included 39 pubic hairs of Caucasian origin and 43 head hairs of Caucasian origin which were dyed black so they could be recognized readily as seed hairs upon recovery. After laundering, the recipient items, non-recipient items, washing machine lint trap and dryer lint trap were examined for seed hairs. Recipient items included a pair of blue jeans, a T-shirt, two pairs of panties, a pair of socks, a dress shirt, a sweatshirt and a towel. Recipient items were laundered with eight non-recipient items including two pairs of socks, a sweatshirt, two dress shirts, and three pairs of panties.

RESULTS AND DISCUSSION

Hairs do occur on items after laundering. Of the 17 laundered items examined for hairs in Phase I, 11 or 65% had human hairs or hair fragments on them. Human head hairs with roots present occurred on 7 or 41% of the items. Animal hairs were found on 71% of the laundered items. Results are listed in Table 1.

Table 1. Phase I Results: Number of Hairs Found on Different Types of Laundered Items

Item	*Composition*	*Human head hairs with root present*	*Human hair fragment*	*Other human hair*[a]	*Animal hair*
1 sweater	acrylic	0	1	0	Yes
2 shirt	cotton/poly[b]	0	1	5 L	Yes
3 shirt	cotton/poly	4	0	1 P	Yes
4 shirt	poly/cotton	7	3	8 L	Yes
5 knit shirt	nylon	3	1	1 B	Yes
6 T-shirt	cotton/poly	6	1	6 L	No
7 shirt	poly/cotton	0	0	0	No
8 shirt	poly/cotton	10	10	1 E	No
9 shirt	poly/cotton	0	1	0	No
10 towel	cotton/poly	0	0	0	Yes
11 sweatshirt	cotton/poly	0	1	0	Yes
12 sweatshirt	cotton/poly	0	0	0	Yes
13 shirt	cotton/poly	1	1	1 E	Yes
14 panties	nylon/cotton	0	0	0	Yes
15 undershorts	nylon	0	0	0	Yes
16 undershorts	nylon	0	0	0	Yes
17 knit shirt	cotton	4	16	2 B	No

[a]Hairs from L=limb, P=pubic, B=body and E=eye
[b]Polyester

At this point in the study it was established that human hairs can be found on laundered items. The next phase of the study was designed to establish whether hairs can be transferred from one item to another as a result of the laundering process.

In Phase II of this study five items from which all human hairs had been removed (Group A) were machine washed and dried with other dirty items (Group B). Human head hairs with roots present were found on two of the five (Group A) items after laundering with the Group B items. It was concluded that hairs can be transferred from one item to another during laundering.

In criminal investigations this would indicate that a secondary transfer has taken place. For example, if a victim's hairs are transferred to a suspect's clothing during commission of a crime and the suspect then washes these clothes, the victim's hairs could be transferred from the suspect's clothes to other items in the laundry. These other items may belong to the suspect or to a third person unrelated to the crime. The possibility of a tertiary or higher transfer exists, making it difficult to discern the significance of hair evidence recovered from laundered items in this example.

In order to further explore what happens to hairs during laundering, the third phase of this study was undertaken. Results are listed in Table 2. Seventy-seven percent of the seed head hairs were recovered as follows: 5% on recipient items, 5% on non-recipient items, 11% in the washing machine lint trap and 56% in the dryer lint trap. Sixty-nine percent of the seed pubic hairs were recovered as follows: 8% on recipient items, 10% on non-recipient items, 10% in the washing machine lint trap and 41% in the dryer lint trap. The missing hairs must have been lost down the drain or somewhere else in the system.

Table 2. Phase III Results: Seed Hairs Found on Recipient and Non-Recipient Items Laundered Together

Item[a]	*Composition*	*Seed hairs*[b] *placed on items before laundering*		*Seed hairs*[b] *found on items after laundering*	
		Inside	*Outside*	*Inside*	*Outside*
R1 blue jeans	cotton	5PH, 4HH	5PH, 5HH	1HH	1PH
R2 T-shirt	cotton	1PH, 2HH	2PH, 3HH	0	0
R3 panties	nylon	3PH, 2HH	1HH	0	0
R4 shirt	cotton/poly[c]	2PH, 3HH	3PH, 4HH	0	0
R5 panties	cotton	5PH	5PH	0	0
R6 towel	cotton/poly	5PH, 6HH	N/A	0	0
R7 sock	acrylic/nylon	1PH	2PH, 4HH	0	1PH
R8 sweat-shirt	cotton/poly	0	9HH	2PH,* 1HH	0
NR1 sweat-shirt	cotton/poly	0	0	0	0
NR2 socks	nylon	0	0	0	0
NR3 sock	acrylic/nylon	0	0	1PH, 1HH	0
NR4 shirt	cotton/poly	0	0	0	0
NR5 panties	nylon	0	0	0	0
NR6 under-shorts	nylon	0	0	0	1PH
NR7 shirt	cotton/poly	0	0	1PH, 1HH	0
NR8 panties	nylon	0	0	0	0

aR= recipient item NR= non-recipient item
[b]Seed hairs were either pubic (PH) or head (HH)
[c]Polyester
N/A= not applicable
*This item was treated as a non-recipient item for pubic hair

CONCLUSION

The following conclusions can be drawn from this study:

1. Human hairs can be found on items after laundering (on 65% of the items in Phase I).
2. Most human hairs are removed from items during laundering (85% of the seed pubic hairs and 90% of the seed head hairs in Phase III).
3. Hair transfers do occur during laundering (Phase II). In fact, hairs that remain on clothes after machine washing and drying are just as likely to be found on the item that they were on before washing as on another item in the laundry (Phase III).

The significance of hair evidence on laundered items must be determined on a case by case basis. The possibility of a secondary or higher level hair transfer resulting from the laundering process may dilute the significance of hair evidence in cases involving a suspect and a victim who launder their clothes or bedding together (e.g. people who share a common household). In

other instances where the victim and suspect are associated only as a result of the crime, it would be useful to examine laundered items for hair evidence based on the results of Phase III which shows that hairs can remain on items through the laundering process.

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GETTING STARTED WITH PYROLYSIS CAPILLARY GAS CHROMATOGRAPHY

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INTRODUCTION

According to a recent survey conducted by the Forensic Science Research and Training Center (FSRTC), more than 130 crime laboratories in the United States use pyrolysis gas chromatography for the examination of forensic samples. The use of this technique has been extensively reviewed, including a recent review in this publication (Wampler and Levy 1985). Pyrolysis capillary gas chromatography has been reported by several laboratories (DeForest 1968, Liebman et al. 1984, Munson and Vick 1985, Kawaoka 1986, and Ryland 1986) and is used by more than 40 crime laboratories (according to the FSRTC survey). Like pyrolysis gas chromatography, capillary gas chromatography has been extensively reviewed, including a recent review in this publication (Stafford 1984). However, judging from the many inquiries received by the FSRTC from examiners at various crime laboratories, there is a need for a "nuts-and-bolts" guide for setting up a system for pyrolysis capillary gas chromatography. Hopefully, this paper will provide such a guide. Rest assured that converting a functioning capillary gas chromatograph (GC) to pyrolysis operation is not difficult. In fact, after the initial installation and hardware modifications described in this paper have been completed, the conversion from the split/splitless injection mode to the pyrolysis mode (or the reverse) can be accomplished with considerable ease. During the Chromatographic Methods in Forensic Science training class, five capillary GC's in the GC Training Laboratory at the FSRTC are converted by one of the instructors from split injection operation to capillary pyrolysis in less than one hour.

MATERIALS AND METHODS

All of the data presented in this report were generated using a Hewlett-Packard (HP) 5890 gas chromatograph connected to an HP 5970B Mass Selective Detector controlled by an HP 236 computer (HP 59970 MS Chemstation using the 3.1 revision software) (Hewlett-Packard Co., Avondale, PA). The figures were drawn by the computer software using an HP 7475A plotter. A DB-5 bonded-phase fused silica column, 30 m by 0.25 mm I.D. with a 0.25 um film thickness (J & W Scientific, obtained from Alltech Associates, Deerfield, IL) was used. The pyrolysis was performed with a CDS Model 120 Pyroprobe system using a coil filament with a quartz sample tube (Chemical Data Systems, Oxford, PA.). The experimental conditions used are presented in Table 1.

Table 1. EXPERIMENTAL CONDITIONS

a. Pyrolysis	
Ramp	off
Temperature setting	800°C
Time	20 sec
Interface temperature *	200°C
Carrier gas flow rate *	50 ml/min
b. Gas Chromatography	
Injector temperature	250°C
Linear velocity at 40°C	70 cm/sec
Carrier gas	Helium
Oven temperature programs	
Grob test mix	30°C for 1 min 15°C/min to 100°C 3°C/min to 250°C
alkane test mix	40°C for 2 min 15°C to 280°C Hold 280°C for 4 min
polyethylene	40°C for 2 min 8°C/min to 300°C Hold 300°C for 21 min
Split ratio	40 to 1
Septum purge	0.5 ml/min
c. Mass Spectrometry	
Transfer line temperature	250°C
Electron multiplier voltage	-1600 volts
Scan range	35 to 350 amu
Scan rates	
Figs 1, 2A, 3A, 3B	2.2 to 2.5 scans/sec
Figs 2B, 4, 5A, 5B, 5C, 5D, 6A, 6B	3.2 to 3.7 scans/sec

* Except as noted otherwise

The following standard reference materials were used in this study: Grob test mix (Cat. No. 4176, Alltech Associates), n-alkane mix (Cat. No. NP-MIX-I, Alltech Associates), and low density polyethylene (ALATHON Type 7, density about 0.925, E. I. DuPont De Nemours, Inc., Wilmington, DE).

EQUIPMENT

Gas Chromatograph

This discussion assumes that one of the commercially available GC's designed for using fused silica open-tubular capillary columns is available and that the operator is proficient in using it. If there are any doubts at this point, study the information supplied by the instrument manufacturer and the aforementioned review article (Stafford 1984) and run some test samples to verify satisfactory performance of the GC before attempting the conversion to pyrolysis.

For proper operation of the pyrolysis system, determine the split ratio (the ratio between the carrier gas flow out the split vent and the flow down the column) for the injector system before and after installation of the pyrolysis interface. The flow out the split vent is measured directly by affixing an appropriate gas-flow measuring device onto the split vent. Measuring the flow down the capillary column is a bit more complicated but still not difficult. One can measure the flow directly, either at the end of the column before it has been connected to the detector or out the detector vent after shutting off all other gas flows to the detector. However, this technique is not very useful for an operating system because it involves disrupting the system. A better method is to measure the retention time of an unretained analyte (such as natural gas, liquid propane gas, or fuel from a disposable cigarette lighter) and calculate the flow rate. The unretained analyte will have eluted in one column volume (consider the column to be a cylinder with a volume equal to pi times the radius squared times the length). The flow in cc/min will be this volume (in cc) divided by the retention time for the unretained analyte in min. If the answer does not come out to be about 1.5 $\pm$ 0.8 cc/min for a 0.25 mm column, an error in measurement, calculation or consistency of units has probably been made. For running the test samples before and after installation of the pyrolysis interface, use a split ratio between 40 and 100 to 1.

Pyrolysis Unit

Of the 138 laboratories which reported performing pyrolysis capillary gas chromatography (in the FSRTC survey), 136 use the Pyroprobe (Chemical Data Systems, Oxford, PA). For the purpose of this discussion, it will be assumed that the pyrolysis unit to be used will be a Pyroprobe.

Capillary Column

A rather bewildering range of choices confronts one when choosing a capillary column. These include choice of supplier, length, internal diameter, and chemical composition of the stationary phase (as well as phase thickness and whether it is coated, bonded or cross-linked), with four to six choices of each except for phase composition, where there are dozens. However, one can make a single choice which will give, if not the best performance, at least a satisfactory performance with all of the samples one will likely encounter as evidence. Such a choice would be a 30 m, 0.25 mm I.D. SE54 bonded-phase (or cross-linked, or bonded and cross-linked) fused silica column with a 0.25 um film thickness. Those who gain experience with the performance of the system with the types of samples run most often may modify this choice to improve some aspect of the pyrograms obtained. A typical temperature program with this SE54 column would be 40^{o}C for 2 min., 15^{o}C/min. to 250^{o}C and hold for 5 min. Once again, a bit of experience will help one select suitable modifications to this temperature program to improve the results for particular samples.

Leak Detection Device

Every laboratory using capillary GC should have an electronic instrument for

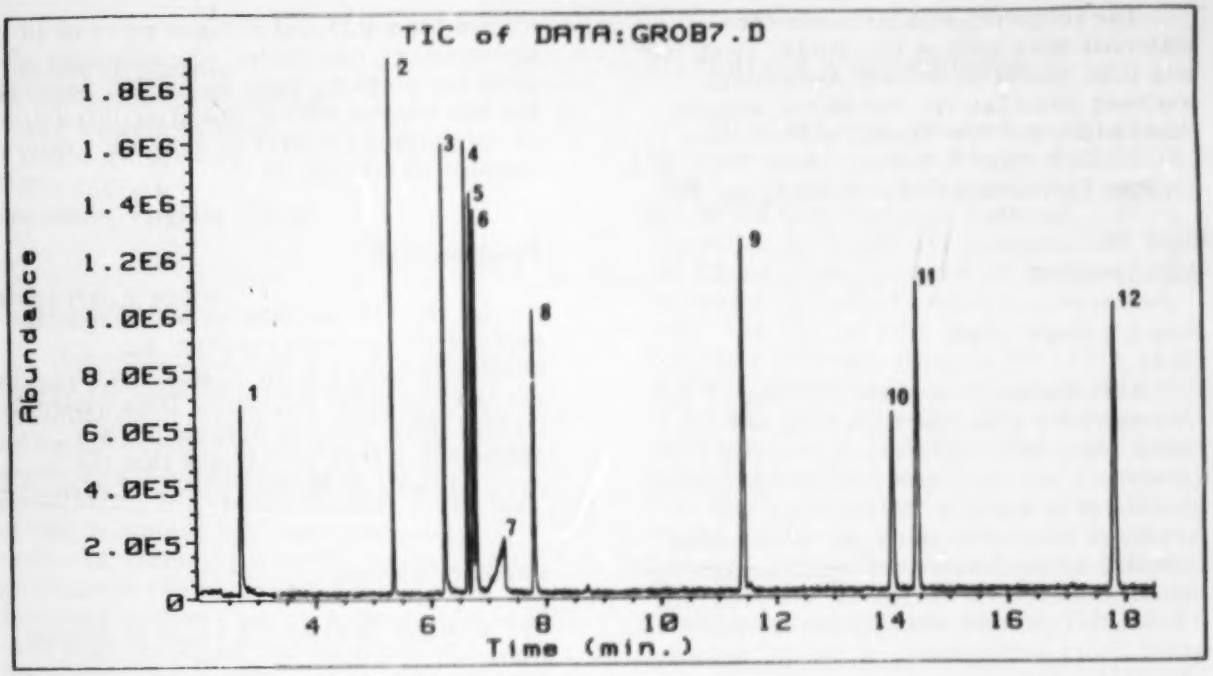

FIGURE 1. Grob test mix: (1) *2, 3-butanediol;* (2) *decane;* (3) *1-octanol;* (4) *undecane;* (5) *nonanal;* (6) *2, 6-dimethylphenol;* (7) *2-ethylhexanoic acid;* (8) *2, 6-dimethylaniline;* (9) *methyl decanoate;* (10) *dicyclohexylamine;* (11) *methyl undecanoate; and* (12) *methyl dodecanoate.*

detecting minute hydrogen and helium leaks. Such a device is especially useful for a pyrolysis system because several leak-prone connections are added to the injector side of the GC gas flow pathway. Although the $700 to $900 initial expense may seem high, leaks at the injector are one of the most common causes of poor chromatographic performance, and such a device can save many hours of frustration by quickly pinpointing the problem. One of the most commonly used devices is the Gow-Mac Leak Detector (available from Supelco, Inc., Bellefonte, PA, as well as other suppliers), although others may be available

INSTALLATION

To perform pyrolysis capillary GC, a heated pyrolysis interface chamber must be installed on the injector of the GC (except for certain Perkin-Elmer GC's which allow for direct insertion of the Pyroprobe into a modified capillary injector). Because addition of the interface will degrade GC performance slightly if done properly, and severely if done improperly, prior to installation it is desirable to establish "benchmarks" against which to measure subsequent performance.

The chromatogram in Figure 1 is of the Grob test mix which can be used for testing the entire injector-column-detector system of the GC. (In Figure 2, the chromatogram obtained using the split/splitless injector is compared to a second chromatogram obtained after installation of the pyrolysis interface). The peak shapes and relative heights indicate whether the system will perform satisfactorily with various classes of acidic, basic, polar and nonpolar chemicals (Grob et al. 1978). Because the components in the Grob test mix are relatively low boiling and because the interface-injector assembly may have one or more "cold spots" depending upon the injector design, a test mixture should be run for later comparison in order to check for possible "cold trapping" of less volatile components. Figure 3A shows the chromatogram obtained for an n-alkane mix (C20, C22, C24, C26)

prior to installation of the pyrolysis interface. It seems self-evident that if the GC system will not perform satisfactorily at this point, the situation will not improve after conversion to pyrolysis.

The function of the interface chamber is to provide a heated space in which the sample can be pyrolyzed and from which the resulting pyrolyzate will be transferred to the GC injector. The interface chamber is connected to the GC injector via a needle assembly provided by the manufacturer of the Pyroprobe. It is necessary to have the needle assembly for the particular GC injector being used because the assembly is designed to replace the GC septum nut and must be the correct size. When a sample is pyrolyzed, the pyrolyzate is swept by carrier gas from the chamber into the injector via the needle assembly. Upon reaching the injector, the pyrolyzate proceeds exactly as if it were a vaporized sample which had been injected into the split injector with a syringe. The installation procedure consists of three important steps: installing the needle assembly, mounting the interface chamber upon the needle assembly, and establishing the carrier gas flow.

The installation of the needle assembly is easily accomplished once the correct size for the injector is obtained. The GC carrier gas is turned off, the pressure is allowed to decrease, and the injector septum nut is removed and replaced with the needle assembly. The needle assembly will probably come with a septum in it, but eventually one will have to be replaced, and there is a problem awaiting the unwary. The needle on the assembly has a small diameter in order to fit into the capillary injector and is very easily plugged by being pushed through a silicone-rubber septum. Prior to replacing the septum in the needle assembly, a hole larger than the needle should be cored through the septum (a gas-tight seal is not required around the needle).

Mounting the interface chamber will be easily accomplished if a new Pyroprobe and the appropriate mounting brackets have been acquired to fit an existing capillary GC. If this is not the case, the Pyroprobe supplier can furnish the appropriate mounting brackets. It is important to mount the interface chamber solidly to the GC because when one is inserting and removing the Pyroprobe from the interface chamber, tightening and loosening the retaining ring which contains the silicone-rubber seal around the probe exerts torque on the interface chamber. This process can stress the seal where the interface chamber connects to the needle assembly and cause leakage of the carrier gas. Adapting a pyrolysis unit from a packed-column GC to a capillary GC can be further complicated if the injectors on both systems are not horizontal (injector axis in the horizontal plane) or vertical, because the interface chamber will be configured for either a vertical or horizontal injector. The interface chamber is designed to keep the axis of the Pyroprobe in the horizontal plane by having the axis of the needle assembly at a 90-degree angle with the axis of the Pyroprobe for a vertical injector and aligned with the axis of the Pyroprobe for a horizontal injector. The chamber for a vertical injector can be used for a horizontal mount by rotating the chamber 90-degrees around both axes if enough space is available on the front of the GC to insert the Pyroprobe into the chamber from the side.

When the interface chamber has been mounted on the needle assembly and affixed to the GC with the appropriate brackets, the remaining installation step is to establish the carrier gas flow. The typical capillary injector has one source of incoming gas and three exiting pathways--down the column, out the split vent and out the septum purge vent. Disconnect the carrier gas supply just before the point where it enters the injector and connect it to the pyrolysis interface chamber. Seal off the fitting on the injector so that gas will not be able to flow out of the injector at this point. The pressure regulator and/or flow controller and all other portions of the capillary injector system will operate in the usual fashion. In the FSRTC GC Training Laboratory, in order to facilitate rapid conversion from pyrolysis to split/splitless injection modes, a three-way valve was installed in the carrier gas line of each GC so that the gas flow pathway change and sealing of the injector connection could be accomplished with a single turn of the valve handle rather than several plumbing changes.

Prior to testing the pyrolysis capillary

GC system, the final task is to pressurize the interface-injector system with the probe inserted (about 15 psi for the 30 m capillary column) and check for leaks. Then heat the interface-injector assembly to operating temperature (at least 150°C for the interface) and check for leaks again.

PERFORMANCE VALIDATION

After the system has been shown to be leak-free, test the performance of the interface-injector assembly by running the test samples again. Remove the Pyroprobe, seal the interface chamber with a septum, establish the same split ratio used for the earlier runs of the test mixes and check around the septum for leaks. Then rerun each of the test mixtures by injecting them directly into the interface chamber.

Figure 2 shows the chromatograms obtained for the Grob test mix with the GC system before (2A) and after (2B) installation of the pyrolysis interface. If everything went well, the chromatograms should be nearly the same as far as peak shape, retention time and peak heights (as those shown in Figure 2 are). If the peak heights and/or peak shapes are poor, the interface-injector assembly may have a leak. If the alkane peaks in the Grob test mix have good shapes and responses but some of the others do not, the hot stainless steel in the pyrolysis interface may be degrading some of the compounds. Repeated pyrolysis of some fairly large samples seems to improve this situation, perhaps by coating or deactivating the reactive sites.

Figure 3 shows the chromatograms obtained for the alkane test mix with the GC system before (3A) and after (3B) installation of the interface. The regular stepwise decrease in the C22, C24 and C26 alkanes when injected into the interface-injector assembly suggests a small amount of "cold-trapping", and hence, slightly degraded performance relative to before installation of the pyrolysis interface, but not enough to adversely affect the analysis of typical forensic samples.

With a pyrolysis system which can pass the tests just enumerated, it should be possible to generate very reproducible pyrograms. If the GC is operating properly, retention times for capillary runs should reproduce within ± 1 sec from one run to the next.

To avoid two problems which can lead to nonreproducible pyrograms, the size of the sample pyrolyzed should be kept small, less than 100 ug, even when large amounts of sample are available. The thermal energy put into the sample during pyrolysis causes bond breakage and the formation of radicals which are fragments of the original polymer molecules. If the concentration of radicals is high enough, rather than forming by intramolecular rearrangement of the radical molecules, some of the components of the pyrolyzate will be formed by radical-radical interactions, thus causing the composition (the number and relative amounts of the chemical components) of the pyrolyzate to vary with the sample size.

Another problem related to sample size can occur if the sample is not completely consumed during the pyrolysis period. Many samples are uniform mixtures of components, such as an evenly layered paint chip or a fragment of tape consisting of backing coated with an adhesive layer. Unless such samples are completely consumed during pyrolysis, differing relative amounts of the various components of the mixture may be produced each time, resulting in differing pyrograms. To test whether a sample has been pyrolyzed to completion, perform a second pyrolysis without removing the probe; obviously, if no peaks appear, no residual sample was present (an assumption underlying this test is that an appropriate system blank has been demonstrated--that is, pyrolysis of an empty quartz sample tube has resulted in no peaks in the pyrogram). If a sample material being pyrolyzed is, in fact, randomly heterogeneous, one should expect the pyrograms for repetitive runs to differ.

Obtaining an appropriate pyrogram from the pyrolysis of a well characterized polymeric material constitutes a suitable test for satisfactory performance of the entire pyrolysis system. Figure 4 presents a pyrogram for low density polyethylene. This material tests the system well for the entire volatility range generally found in pyrograms, and it will be used here to demonstrate potential problems with two operating

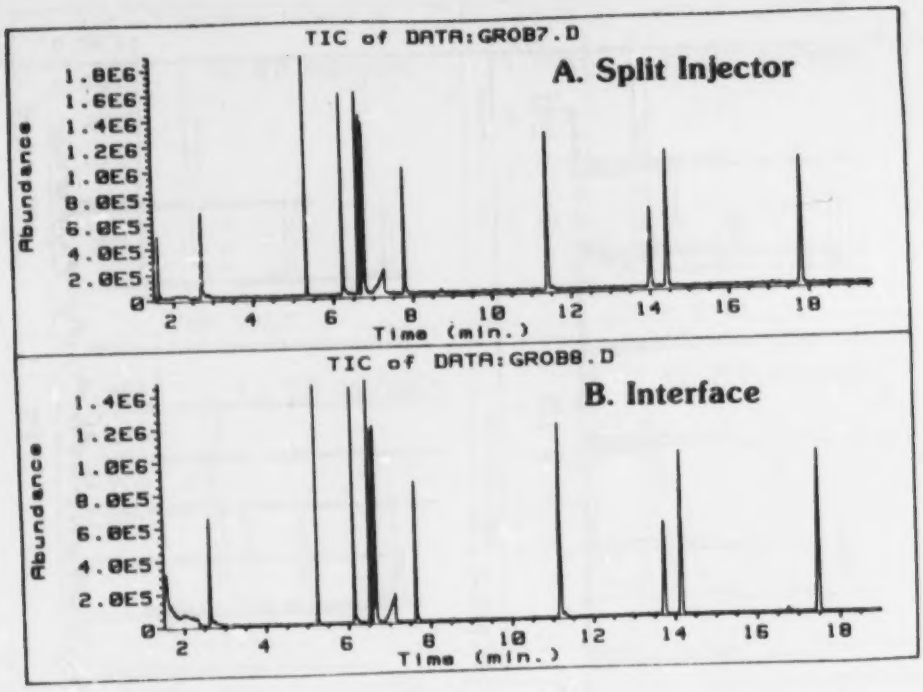

FIGURE 2. Comparison of Grob test mix in (A) *split injector; and* (B) *interface.*

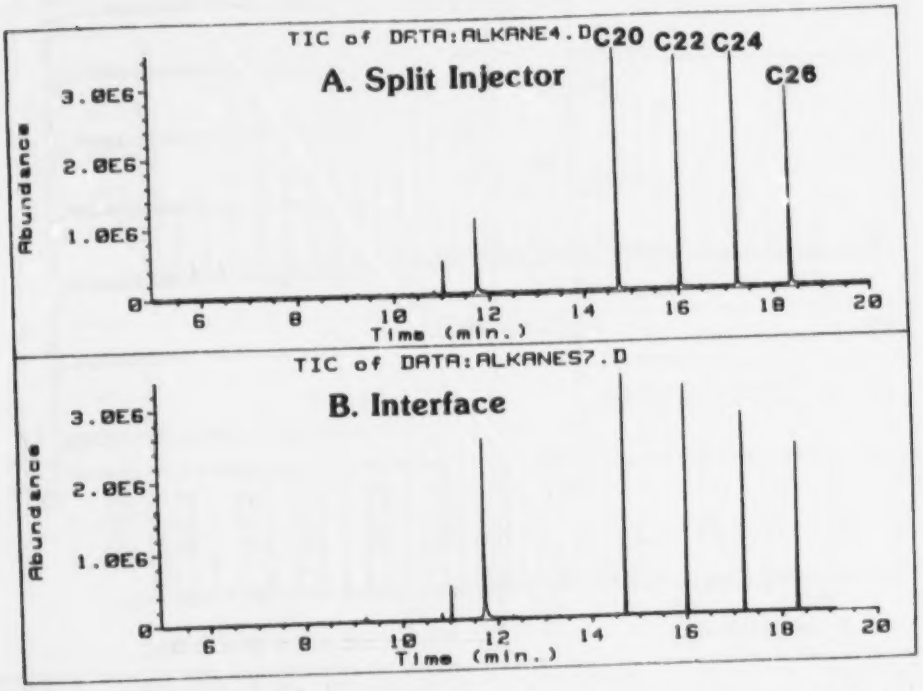

FIGURE 3. Comparison of alkane test mix in (A) *split injector; and* (B) *interface.*

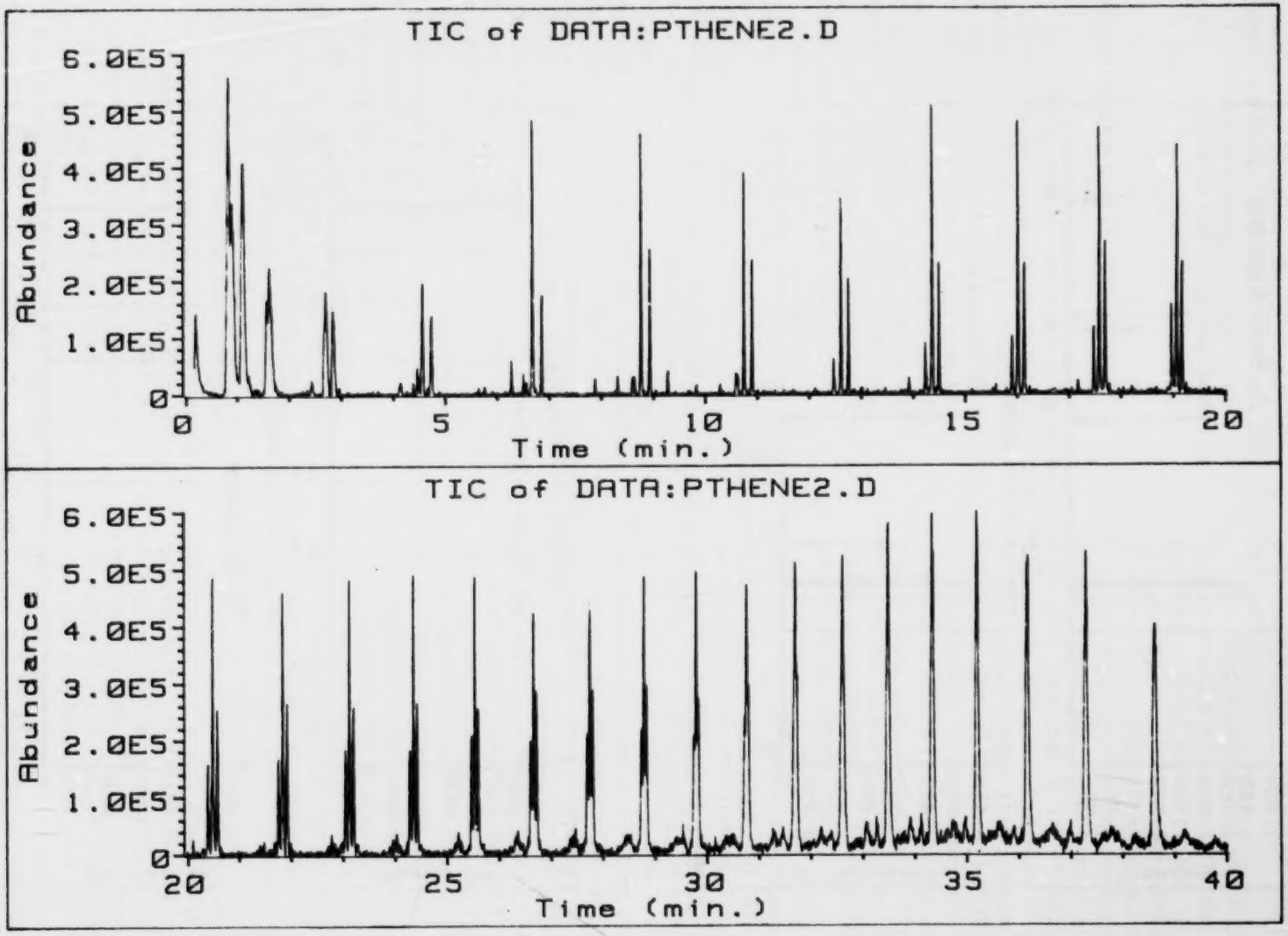

FIGURE 4. Capillary pyrogram of polyethylene.

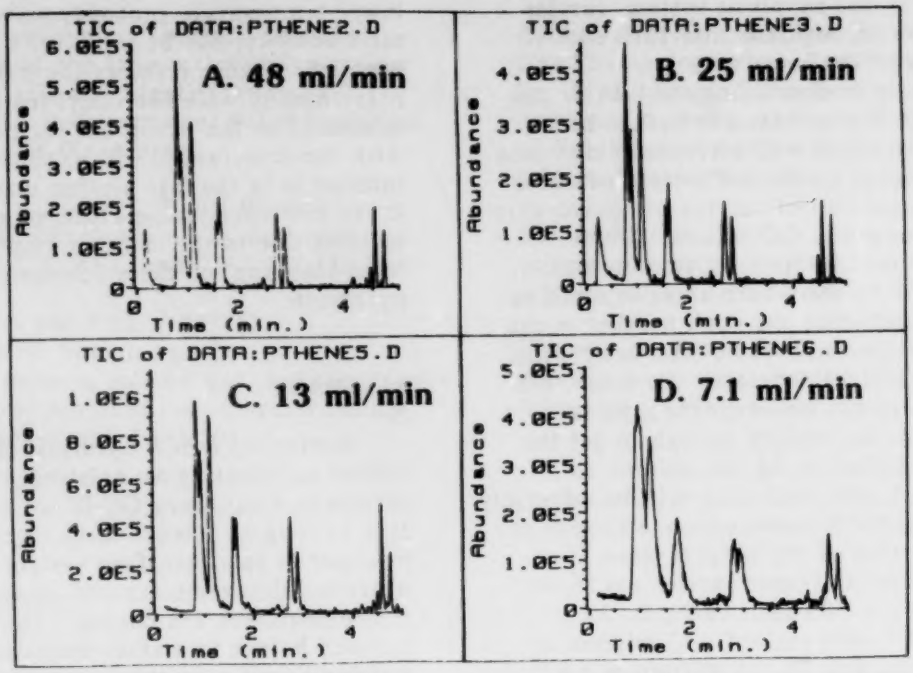

FIGURE 5. Comparison of a portion of the polyethylene pyrogram with interface carrier gas flows of: (A) *48 ml/min.;* (B) *25 ml/min.;* (C) *13 ml/min.; and* (D) *7.1 ml/min.*

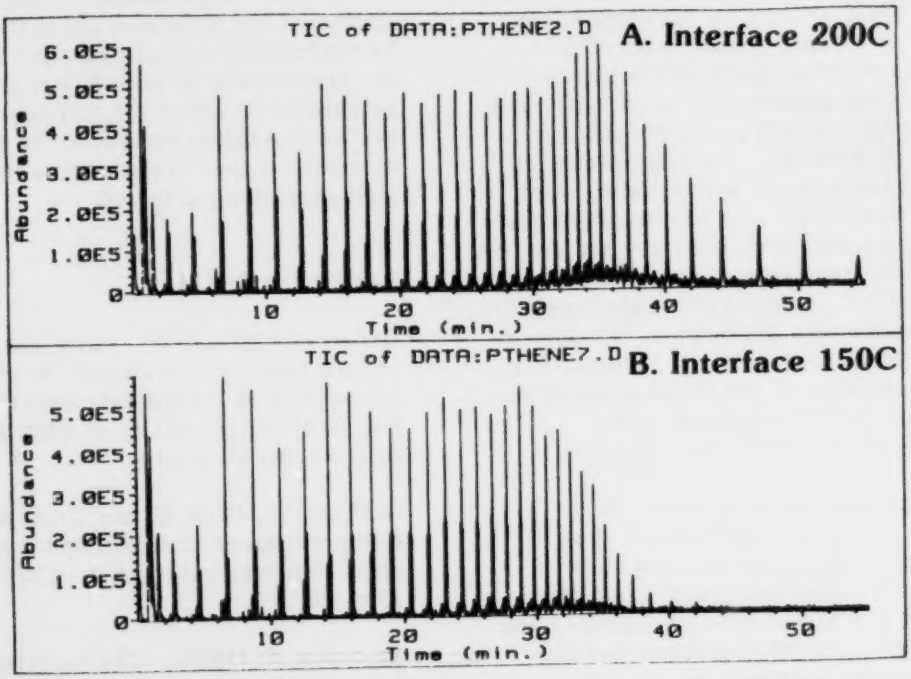

FIGURE 6. Comparison of the polyethylene pyrogram at interface temperatures of (A) *200°C; and* (B) *150°C.*

parameters of the pyrolysis system--carrier gas flow rate through the interface and temperature of the interface.

Increasing or decreasing the carrier gas flow through the pyrolysis interface at a given head pressure will increase or decrease the split ratio and concomitantly decrease or increase the amount of the sample pyrolyzate which goes onto the GC column. When routinely working with very small samples, one may wish to use a split ratio as small as possible to maximize the peak heights in the pyrogram. If the split ratio (and hence, the carrier gas flow) is decreased too much, the pyrolyzate will not be swept through the capillary injector rapidly enough to get the components added to the GC column as narrow bands, and resolution will be adversely affected. Figure 5 shows expanded views of the early portion of the polyethylene pyrogram using different carrier gas flows: A., 48 ml/min, a 38:1 split ratio; B., 25 ml/min, a 20:1 split ratio; C., 13 ml/min, a 10:1 split ratio; and D., 7.1 ml/min, a 5.6:1 split ratio. The sample size was decreased along with the split ratio in an attempt to keep the peak heights comparable. The resolution of those components which elute from the column prior to five min. is considerably diminished by the lowest flow rate. For this system, a split ratio of 10:1 appears to give satisfactory performance; however, anyone planning to use a split ratio of less than 20:1 should perform this experiment to determine the characteristics of the interface-injector system being used. This loss of resolution was not observed for the components which eluted from the column after five min., probably due to a band-narrowing effect resulting from condensation of the components at the head of the column at the start temperature. If the information in the early portion of the chromatogram is of no interest, the splitless injection technique might be useful for very small samples.

Some analysts prefer to have the pyrolysis interface at 150°C rather than 200°C because the probe seal area stays cooler, perhaps reducing "bleed" from the silicone-rubber seal as well as prolonging the life of the seal and causing fewer burned fingers. For most forensic samples, the lower temperature probably serves quite satisfactorily, but be aware of a potential problem. Figure 6 shows the pyrogram for polyethylene with the interface at 200°C (6A) compared to the pyrogram for polyethylene with the interface at 150°C (6B). If the main interest is in the late eluting materials, the lower interface temperature may not be suitable due to the rather serious "cold-trapping" of these components of the pyrogram.

SUMMARY

Setting up a new pyrolysis capillary GC system or adapting an existing pyrolysis GC system to a capillary GC is not a difficult task as long as correct carrier gas flow is established in a leak-free system and suitable operational parameters and compatible instrumentation are chosen. The use of test samples before and after installation of the pyrolysis unit onto the injector of the GC should indicate the source of most problems which may be encountered, as well as verify the proper performance of the pyrolysis capillary GC system.

If after some period of successful operation the pyrolysis GC system seems to be performing unsatisfactorily based upon the appearance of sample pyrograms, it might be helpful to rerun the test samples prior to taking corrective measures. It may be determined that the system is not malfunctioning after all.

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REGIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

The Southern Association of Forensic Scientists (SAFS) will hold their 20th Anniversary Fall Symposium at the Auburn Conference Center in Auburn, Alabama from September 10-13, 1986.

The Program Chairman for the symposium is Ronald Singer. He can be contacted at the Jefferson Parish Crime Laboratory, 3300 Metairie Road, Metairie, Louisiana 70001 (telephone: 504-832-2320).

For further information, contact Carlos L. Rabren, Alabama Department of Forensic Sciences, P.O. Box 231, Auburn, Alabama 36831-0231 (telephone: 205-887-7001).

The Midwestern Association of Forensic Scientists (MAFS) will hold their 15th Anniversary Meeting in Springfield, Illinois from October 7-10, 1986.

The Program Chairman for the meeting is Ted Elzerman. He can be contacted at the Illinois Department of State Police, Bureau of Forensic Sciences, 726 South College Street, Springfield, Illinois 62707 (telephone: 217-782-4649).

For information regarding local arrangements, contact John Klosterman at the address listed above.

The Northwest Association of Forensic Scientists (NWAFS) will hold their Fall 1986 meeting at the Red Lion Riverside in Boise, Idaho from October 8-10, 1986.

For further information, contact Pam Server, Forensic Section, Bureau of Laboratories, 2220 Old Penitentiary Road, Boise, Idaho 83712 (telephone: 208-334-2231).

The California Association of Criminalists (CAC) will hold their Fall Semi-Annual Seminar at the Gene Autry Hotel in Palm Springs, California from October 8-11, 1986.

For further information, contact Faye Springer, California Department of Justice Forensic Laboratory, 1500 Castellano Road, Riverside, California 92509 (telephone: 714-782-4170).

The Mid-Atlantic Association of Forensic Scientists (MAAFS) will hold their Fall 1986 meeting at the Carousel Hotel in Ocean City, Maryland from October 23-24, 1986.

For further information, contact Amy Wong, Northern Regional Forensic Laboratory, P.O. Box 486, Merrifield, Virginia 22116 (telephone: 703-573-8636).

The Northeastern Association of Forensic Scientists (NEAFS) will hold their 12th Annual Meeting in Peabody, Massachusetts from October 24-25, 1986.

For further information, contact Dr. William Adams, Department of Chemistry/Physics, Salem State College, Salem, Massachusetts 01970 (telephone: 617-745-0556, ext. 2526).

The Midwestern Association of Forensic Scientists (MAFS) will hold their Fall 1987 meeting on Mackinac Island, Michigan from October 6-9, 1987. This meeting will be hosted by the Michigan State Police Forensic Science Division.

For further information, contact Richard E. Bisbing, Michigan State Police Laboratory, 6296 Dixie Highway, P.O. Box H, Bridgeport, Michigan 48722 (telephone: 517-777-9300).

NATIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

A symposium on forensic chemistry will be held in conjunction with the Annual Federation of Analytical Chemistry and Spectroscopy Societies Meeting from September 28 - October 3, 1986 at the Cervantes Convention Center in St. Louis, Missouri. Special consideration will be

given to presentations discussing forensic applications of infrared and atomic spectroscopies, but other topics will be considered. The deadline for submitting titles is February 3, 1986.

For further information about the symposium, contact Dr. Robert Koons, FSRTC, FBI Academy, Quantico, Virginia 22135 (telephone: 703-640-6131).

The 39th Annual Meeting of the American Academy of Forensic Sciences will be held at the Town & Country Hotel in San Diego, California from February 16-21, 1987.

The theme of the meeting is "Biohazards in the Environment." Planned activities include plenary sessions and presentations of scientific papers. Abstracts should be forwarded by August 1, 1986.

For further information, contact the American Academy of Forensic Sciences, 225 S. Academy Boulevard, Colorado Springs, Colorado 80910 (telephone: 303-596-6006).

INTERNATIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

The Japanese Society of Electron Microscopy and the Science Council of Japan will host the XIth International Congress on Electron Microscopy (XI ICEM). The congress is scheduled for August 31 - September 7, 1986 in the Okazaki area of the city of Kyoto. The congress will be devoted to plenary sessions, symposia, workshops, public lectures and poster and/or oral presentations of contributed papers. Emphasis will be placed on the poster sessions. Symposia and workshops on recent topics in the technology and application of electron microscopy are among the scheduled activities. The official language of the XI ICEM is English.

For further information, contact Professor Kazuo Ogawa, Chairman, Executive Committee of the XI ICEM, Department of Anatomy, Faculty of Medicine, Kyoto University, Konoecho, Yoshida, Sakyoku, Kyoto 606, Japan (telephone: 075-751-7727; telex: 05422693 LIBKYU J).

The International Committee on Alcohol, Drugs and Traffic Safety (ICADTS) announces the 10th International Conference on Alcohol, Drugs and Traffic Safety to be held at the RAI-Congress Centre in Amsterdam, Netherlands from September 9-12, 1986.

The purpose of this conference will be to present the state of the art on Alcohol, Drugs and Traffic Safety. Through the years, attention has shifted from alcohol to alcohol and other drugs and from contributions by the medical and legal professions to other professions involved in safety research. These changes will be emphasized in this year's program. Special attention will be given to the role of drugs other than alcohol and on the application of available scientific knowledge to safety actions.

The provisional program includes sections on the following: experimental studies on the detrimental effects of alcohol and other drugs, epidemiology, general preventive actions, special preventive actions, systematic analysis and evaluation of potential counteractions. Keynote speakers will be invited to present state-of-the-art reviews for each part of the program. Papers of other speakers are expected to provide new empirical evidence in the fields of interest. Contributions of a technical or specialist nature will be concentrated in workshops or other special events such as poster sessions. Exhibition facilities will be provided.

The Chairman for the conference is C. L. A. Heijster.

For further information, contact Symposium Secretariat, QLT Convention Services, Keizersgracht 792, 1017 EC Amsterdam, Netherlands (telephone: 020-261372; Telex: 31578 inter nl. att. QLT)

The Canadian Society of Forensic Science will hold their 33rd Annual Meeting at the Sheraton-Brock Hotel in Niagara Falls, Ontario from September 15-19, 1986.

The theme of this year's meeting is "Environmental Risks and Forensic Science." This theme will be covered from a medical, legal, toxicological and environmental perspective.

The meeting will be devoted to plenary sessions, workshops and scientific sessions.

A plenary session on aircraft disasters is scheduled. A film entitled "Operation Overdue" which deals with the crash of the New Zealand Airline DC-10 into Mount Erebus will be shown. Also within this plenary session will be a presentation by an on-site investigator of the Air India 747 crash into the North Atlantic. Other presentations include Mass Disaster - Computerization, Impression and Casting Material Selection for Bite Impressions on Non-Living Subjects and Armamentarium for use in Forensic Odontology. Planned workshops include Gm-Km Blood Typing, Fiber Textile Identification and Manufacture, and Interpretations and Influence of Drugs on Driving.

Scientific papers are requested for presentation at this meeting. Titles and abstracts should be forwarded by July 15, 1986 to the Canadian Society of Forensic Science, 2660 Southvale Crescent, Suite 215, Ottawa, Ontario, Canada K1B 4W5 (telephone: 613-731-2096).

For further information, contact either Dr. Ray Prime, Program Coordinator or JoAnne Cottingham, Executive Secretary at the address listed above.

The Society for Forensic Haemogenetics will hold their 1986 Annual Seminar from October 23-24, 1986 at the Ministry of Justice in the Hague, the Netherlands. The major theme of this seminar is the application of DNA polymorphism to medical-legal problems.

For further information, contact A. D. Kloosterman, Dutch Forensic Science Laboratory of the Ministry of Justice, Volmerlaan 17, 2288 GD RIJSWIJK (Z.H.), The Netherlands (telephone: 70-408131)

The International Association of Forensic Toxicologists will hold their 24th Annual Meeting in Banff, Alberta, Canada from July 28-31, 1987. Among the planned activities is a special session on Postmortem Changes Affecting Toxicology.

Confirmed reservations are required. The deadline for making reservations is January 1, 1987.

For further information, contact Dr. Graham R. Jones, TIAFF 87, 4070 Bowness Road N.W., Calgary, Alberta, Canada T3B 3R7 (telephone: 403-427-4987).

The International Association of Forensic Sciences 11th Meeting will be held at the Hotel Vancouver in Vancouver, British Columbia, Canada from August 2-7, 1987. The meeting will be structured around plenary sessions, short paper sessions, technical exhibits, poster sessions and an arts and crafts exhibition. Special presentations by the International Academy of Legal Medicine and Social Medicine, and the International Study Group on National Unexpected Deaths are scheduled for the meeting. Plenary sessions include Collection and Presentation of Evidence, Conduct of a Criminal Trial and Sentencing the Offender.

Abstracts should be forwarded by December 31, 1986 to the International Association of Forensic Sciences, Suite 801, 750 Jervis Street, Vancouver, British Columbia, Canada V6E 2A9 (telephone: 604-681-5226).

INSTRUCTIONS FOR SUBMITTING ARTICLES

In order to facilitate rapid publication, submissions should conform to the following:

1. Manuscripts should be typed, double-spaced, on 8 1/2" x 11" paper. Submit three copies of the manuscript (one of which must be the original with glossy photographs).

2. Tables should be as simple as possible. Each table should be typed on a separate sheet of paper and should include a heading.

3. Graphs and diagrams should be submitted as sharp photographs on white glossy paper.

4. References in the body of the paper should refer to the author's (authors') name(s) and the date of publication. For example:

   According to Doe and Smith (1972)....

   ....has been discussed in the literature (Doe and Smith 1972; Weinburger et al. 1984; Jones 1981).

5. References at the end of the paper should appear in alphabetical order. Journal references should include the author's (authors') name(s), date of publication, title of article, journal name, volume number, and the beginning and ending pages of the article. Please use the following format:

   Davis, H. E. and Jones, B. A. (1978). Seasonal variations in plasma hormones, Biol. Reprod. 88:271-273.

   List articles or chapters within a book as follows:

   deHaseth, J. A. (1982). Fourier transform infrared spectrometry. In: Fourier, Hadamard and Hilbert Transformations in Chemistry, (Marshall, A. G., ed.) Plenum Press, New York, pp. 387-420.

6. Technical papers should be written in an Introduction, Materials and Methods, and Results and Discussion format.

7. When reference is made to a particular product, state the manufacturer of the product and the city and state of the manufacturer's headquarters. For example:

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October 1986
Volume 13, No. 4

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Crime Laboratory Digest

Review Article In This Issue:

Spectrographic Voice Identification

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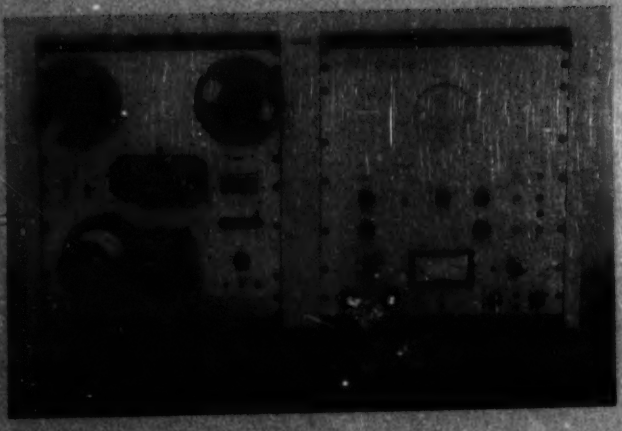

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(This Issue Completes Volume 13)

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PUBLICATION POLICY

The Crime Laboratory Digest is published quarterly by the FBI Laboratory in cooperation with the American Society of Crime Laboratory Directors (ASCLD). It is intended to serve as a rapid means of communication between crime laboratories, permitting information of interest and value to be disseminated among crime laboratory scientists.

Inclusion of an article in the Crime Laboratory Digest in no way represents an endorsement or recommendation of any part of that article by the Federal Government, the Department of Justice or the FBI. Contributing authors assume total responsibility for the contents and accuracy of their submission. Questions or requests concerning an article should be directed to the contributing agency.

All submissions are subject to editorial review in accordance with the editorial policy established by the FBI Laboratory and ASCLD. The editorial staff of the Crime Laboratory Digest reserves the right to edit all articles for style, grammer and punctuation. Comments and letters to the editor are encouraged and will be published when appropriate and as space permits. These should be forwarded to:

Crime Laboratory Digest - Editor
FSRTC, FBI Academy
Quantico, Virginia 22135

CRIME LABORATORY DIGEST Vol 13, No. 4, October 1986
ISSN NO. 0743-1872

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ON THE COVER

The cover, prepared by the Special Projects Section of the FBI Laboratory, depicts an analog sound spectrograph and two examples voice spectrograms.

MESSAGE FROM THE ASSISTANT DIRECTOR IN CHARGE OF THE FBI LABORATORY

This October 1986 issue of the Crime Laboratory Digest has been delayed so that we could include the schedule of specialized scientific schools to be held this fiscal year. The delay has been caused by scheduling uncertainty due to an increase in the number of new FBI and DEA Agents that are to be trained at the FBI Academy during this fiscal year. The increase in the number of new Agents has created a burden on the facilities for housing and classroom space. Until the scheduling and logistics for coordinating the training of the new Agents could be worked out, we were unable to schedule the specialized scientific courses for the law enforcement community. A list of the courses to be offered in FY 87 appears in the Editor's Column, and as you examine the list you will note we have attempted to offer those courses that have been most frequently requested in the past. Lastly, I would like to note that despite the increased demand for the training facilities at the FBI Academy, we are able to offer an international symposium this fiscal year. The FBI Identification and Laboratory Divisions are cohosting a symposium on Latent Print Detection, scheduled for July 8-11, 1987. We are pleased to be able to offer these programs to the forensic community.

ROBERT S. GAST II

With this issue of the Crime Laboratory Digest we complete Volume 13. The editorial staff wishes to take this opportunity to thank those individuals who have contributed their time and energies to make this publication possible. We thank the following members of the editorial board for reviewing technical articles: W. Anderson, F. S. Baechtel, R. Cravey, H. A. Deadman, P. R. DeForest, D. D. Fetterolf, B. D. Gaudette, H. Lee, T. O. Munson and A. G. Podolak.

Humagen, Inc. Charlottesville, Virginia, has recently begun to market two immunoassay products for the identification of body fluids. The SEMA™ kit is designed to detect a protein secreted into semen, and the HUMAN I.D.™ kit is used for the detection of human albumin in body fluid stain extracts. The FBI contracted with the University of Virginia Medical School, Charlottesville, to develop monoclonal antibodies for forensic stain characterization. Two monoclonal reagents were developed under this contract, one for human semen and the other for human serum albumin. The University of Virginia determined that these reagents might have some commercial value. The license to produce and market these reagents was awarded by the University of Virginia to Humagen, Inc. Neither kit product is currently being used by the FBI Laboratory for the examination of case evidence. Both of these products remain in the evaluation and validation stages at the Forensic Science Research and Training Center. Any change in this status will be reported in this publication, or others, as appropriate.

The FBI Laboratory was asked if employment opportunities in the forensic community might again be listed in the Crime Laboratory Digest. The following is a list of positions that are currently open:

Criminalist III: The Washington State Patrol is currently seeking applicants with a strong background in serology for a Criminalist III position at its laboratory in Kennewick, Washington. Minimum qualifications include a Bachelor of Science degree, which includes at least 20 semester hours of chemistry and 4 years full-time paid technical experience in an analytical laboratory, 3 years of which must have been in a forensic science laboratory, with 2 years experience in serology. Salary range: $2,117 - $2,710 per month. Submit applications to John F. Anderson, Technical Director, Washington State Patrol, Crime Laboratory Division, General Administration Building, AX-12, Olympia, WA 98504 (telephone: 206-753-4073). The State of Washington is an Equal Opportunity Employer.

Forensic Chemist I, II, III: The Crime Laboratory Division of the Maryland State Police is seeking applicants for Forensic Chemist positions. Minimum qualifications for the Forensic Chemist I position are a Bachelor of Science degree in chemistry, forensic science, biology or other physical science, including or supplemented by 24 semester hours in chemistry and/or biology and including 3 semester credit hours in instrumental analysis. No experience is required. Salary range: $15,567 - $20,391 per year.

Additional requirements for the Forensic Chemist II position include 1 year of experience in forensic science work and testifying in a criminal court as an expert witness in at least one field of evidence, such as trace evidence, drugs or explosives. Salary range: $19,391 - $25,463 per year.

Further requirements for the Forensic Chemist III position include 3 years of experience in forensic work and regularly testifying in criminal court for 2 years as an expert witness in at least two fields evidence. Salary range: $22,492 - $29,551 per year. Submit applications to the Maryland State Police, Personnel Management Division, 1201 Reisterstown Road Pikesville, MD 21208 (telephone: 301-653-4349). The State of Maryland is an Equal Opportunity Employer.

Forensic Scientist II: The Palm Beach County Sheriff's Department Crime Laboratory is seeking applicants for a Forensic Scientist II (Serologist) position. Minimum qualifications include a Bachelor of Science

degree in chemistry, forensic science, biology or a closely related field and 3 years of experience as a fully qualified forensic serolgist. Additional education may be substituted for some experience. Candidates must be able to perform the full range of current forensic serology techniques (both Antigen and Enzyme Procedures), report on the results and testify in court. Salary range: $27,516 - $33,176 per year, commensurate with qualifications. Submit applications to Richard L. Tanton, Director, Palm Beach Sheriff's Crime Laboratory, 3228 Gun Club Road, West Palm Beach, FL 33406 (telephone: 305-471-2220). The county of Palm Beach is an Equal Opportunity Employer.

Latent Print Examiner: The Oakland Police Department Crime Laboratory is currently seeking applicants for a Latent Print Examiner position. Candidates who are certified by the International Association of Identification (IAI) or who meet current experience and education requirements for certification, including a Bachelor of Science degree, are preferred. Salary range: $2312 - $2552 per month. Submit applications to Jan S. Bashinski, Laboratory Director, Oakland Police Department, 455 Seventh Street, Room 608, Oakland, CA 94607 (telephone: 415-273-3386). The city of Oakland is an Equal Opportunity Employer.

Questioned Document Examiner: The city of Houston is currently seeking applicants for a Questioned Document Examiner position. Candidates must have at least 2 years experience in a recognized forensic laboratory, good working knowledge of techniques, equipment and examination procedures and experience in giving courtroom testimony. A Bachelor of Science degree in a natural or physical science field is preferred. Salary range: low to middle $30,000's per year, commensurate with qualifications and experience. Submit applications to Tom Anger, Personnel Department, City of Houston, P.O. Box 1562, Houston, TX 77251. The city of Houston is an Equal Opportunity Employer.

SPECIALIZED SCIENTIFIC SCHOOLS FY 87

The following is a list of specialized scientific courses which will be offered by the FBI in FY 87. These schools are conducted at the FSRTC at the FBI Academy and are available for crime laboratory and law enforcement personnel throughout the United States. Information pertaining to these courses can be obtained through your crime laboratory director or local FBI Police Training Coordinator.

( ) Indicates Number of Students per Class

Laboratory Examinations in Arson Matters (12)
- 2/22 - 27/87
- 6/7 - 12/87

Police Arson Crime Scene Investigators (24)
- 8/2 - 7/87

Chromatographic Methods in Forensic Science (12)
- 1/25 - 2/6/87
- 3/8 - 20/87
- 7/19 - 31/87

Instrumental Analysis of Paints & Plastics (12)
- 2/8 - 13/87

Instrumental Analysis of Explosives & Explosive Residues (12)
- 3/22 - 27/87

Survey of Forensic Glass Examinations (12)
- 3/8 - 13/87

Fundamentals of Document Examination for Laboratory Personnel (13)
- 2/22 - 3/6/87
- 8/2 - 14/87

Introduction to Hairs & Fibers (12)
- 1/25 - 2/6/87
- 5/31 - 6/12/87
- 7/19 - 31/87

Collection & Preservation of Physical Evidence (24)
8/9 - 14/87

Basic Forensic Serology (14)
1/25 - 2/6/87
7/19 - 31/87

Biochemical Methods in Bloodstain Analysis (12)
11/30 - 12/12/86
5/31 - 6/12/87

Bombing Crime Scene School (26)
9/13 - 18/87

Specialized Techniques in Firearms Identification (12)
2/1 - 6/87
5/17 - 22/87

Gunpowder & Primer Residues (14)
8/30 - 9/4/87
9/20 - 25/87

Atomic Absorption for Primer Residues (8)
9/13 - 18/87

Crime Laboratory Forensic Photography (12)
4/12 - 5/1/87
5/10 - 29/87

Police Photography (12)
8/23 - 9/4/87

Police Composite Artist (14)
11/30 - 12/12/86
6/7 - 19/87

The Detection & Examination of Footwear Impression Evidence (15)
2/8 - 13/87
7/12 - 17/87

Administrative Advanced Latent Fingerprint Course (20)
11/30 - 12/19/86
9/13 - 10/2/87

Latent Fingerprint Photography (12)
1/4 - 16/87
2/22 - 3/6/87
7/12 - 24/87

Forensic Gambling Seminar (16)
2/8 - 13/87

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON THE ANALYSIS AND IDENTIFICATION OF POLYMERS

This 176-page publication is the proceedings of an international forensic science symposium on the analysis and identification of polymers which was hosted by the FBI Laboratory at the Forensic Science Research and Training Center, FBI Academy, Quantico, Virginia 22135, July 31 - August 2, 1984. This publication contains the manuscripts of the 11 plenary lectures which covered such topics as "Forensic Analytical Pyrolysis," "Fundamentals of the Polymer Chemistry of Acrylics and Vinyls," "Forensic Analysis of Polymers at the Metropolitan Police Forensic Science Laboratory" and "Trends in Polymer Development and Analytical Techniques." In addition, it contains the extended abstracts of 12 of the 17 short presentations made and a summary of the panel discussion, "Standardization Procedures." This publication, entitled "Proceedings of the International Symposium on the Analysis and Identification of Polymers," is available from the U.S. Government Printing Office (GPO). The GPO stock number is 027-000-01265-5. Requests for this publication should be directed to:

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CENTRAL RESEARCH ESTABLISHMENT REPORTS

The Central Research Establishment (CRE), Home Office Forensic Science Service, Aldermaston, Reading, England, has provided the FBI Laboratory with copies of CRE Reports on completed research projects. By mutual agreement between the FBI and the CRE, these reports are available to all duly authorized law enforcement organizations in the United States. To obtain these reports, send a request from your crime laboratory director to:

Federal Bureau of Investigation
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Room 3589
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The following CRE Reports are now available:

The Influence of Latent Fingerprint Detection Techniques on the Subsequent ABO and Gm/Km Typing of Dried Bloodstains, J. I. Hussain, E. Patrick, C. Ragoonanan and C. A. Pounds, CRE Report #590

A Fibre Data Collection for Forensic Scientists - Collection and Examination Methods, D. K. Laing, A. W. Hartshorne, R. Cook and G. Robinson, CRE Report #591

Report of a Survey Concerning the Exposure of Individuals to Breaking Glass, J. A. Zoro and M. J. Fereday, CRE Report #592

An Investigation of Flash Heating as a Sample Preparation Method for Small Glass Fragments Prior to Analysis in the Scanning Electron Microscope, J. A. Zoro and D. M. Burt, CRE Report #593

A Preliminary Investigation of Refractive Index Anomalies at the Surface of Glass Objects and Windows, J. A. Zoro, J. Locke, R. S. Day, O. Badmus and A. Perryman, CRE Report #594

The Use of Biological Dyes for Revealing Latent Fingerprints. Part 2 - Operational Trials to Compare Performance of Sudan Black B with Metal Deposition and Small Particle Reagent on Plastic Surfaces, C. A. Pounds and J. M. Strachan, CRE Report #595

The Definition of Colour for Single Textile Fibres by Microspectrophotometry. Part 1, A. W. Hartshorne and D. K. Laing, CRE Report #597

The Definition of Colour for Single Textile Fibres by Microspectrophotometry. Part 2, A. W. Hartshorne and D. K. Laing, CRE Report #598

High-Performance Liquid Chromatography Systems for the Analysis of Analgesic and Non-steroidal Anti-inflammatory Drugs in Forensic Toxicology, H. M. Stevens and R.Gill, CRE Report #599

The Use of Non-Routine Techniques to Reveal Fingerprints at Scenes of Crime: A Joint Home Office/Metropolitan Police Project, C. A. Pounds, K. E. Creer, E. F. Pearson and I. T. Lucas, CRE Report #600

The Separation of LSD from Related Ergot Alkaloids and Its Identification in Forensic Casework Samples, M. Japp, R. Gill and M. D. Osselton, CRE Report #601

The Effectiveness of Bronze Powder in Revealing Latent Fingerprints, C. A. Pounds, CRE Report #602

FORENSIC SCIENCE INFORMATION RESOURCE SYSTEM

The Forensic Science Information Resource System (FSIRS) is a forensic science library housed in two facilities: at FBI Headquarters in Washington, D.C. and at the FBI Academy in Quantico, Virginia. The FSIRS was established in 1985 to provide information services to the FBI Laboratory Division and to authorized crime laboratories in the United States and foreign countries. The information services include literature searches and document delivery. Colleen Wade, Librarian, and Cindy Poyer, Technical Information Specialist, provide the services.

Literature Searches

The FSIRS subscribes to DIALOG Information Services, Inc. which currently provides access to over 250 multidisciplinary databases online. Upon receipt of an information request, a search strategy is formulated and entered into the computer. The literature search results include bibliographic citations, often with abstracts. The search results are printed and mailed to the requestor.

Document Delivery

An essential part of information services is providing copies of the journal articles, government documents or proceedings cited in a literature search. Upon request, the documents will be obtained by searching the FSIRS collections as well as federal and

academic libraries in the metropolitan Washington, D.C. area. The documents may also be purchased through document delivery services.

Requesting Information Services

Literature searches and document delivery are available to all duly authorized crime laboratories. Presently, the information services are free of charge. To obtain these services, send a written request from your crime laboratory director, utilizing the forms included on pages 103 and 104 to:

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SPECTROGRAPHIC VOICE IDENTIFICATION

Bruce E. Koenig
Engineering Section
Technical Services Division
Federal Bureau of Investigation
Lorton, Virginia 22079

Spectrographic voice identification or "voiceprint" analysis is a forensic laboratory procedure normally used to compare tape recorded unknown telephone callers with known voice exemplars of suspects in investigations ranging from false fire alarms to kidnapping and espionage. Similar to handwriting analysis, this technique requires that the same words be compared between voice samples; therefore, in most voice exemplars the suspect repeats verbatim the words used by the unknown caller. Legal and scientific acceptance of this voice identification examination has been mixed since its forensic introduction in the 1960's, and only a relatively few crime laboratories and private practitioners use the analysis. In fact, during the last decade there has been a decline in the number of active examiners. Critics have stated that spectrographic comparisons are no more accurate than listening tests alone and that the visual comparisons are only utilized to add a false sense of scientific objectivity. Conversely, many practitioners have testified that the examination is a positive and repeatable process for identifying unknown callers in law enforcement situations. A newly published 1986 survey of the Federal Bureau of Investigation's (FBI's) long-term experience with the technique found a small, but measurable error rate even when rigid standards were followed (Koenig 1986).

SPEECH PRODUCTION

Since spectrographic analysis requires the comparison of similar speech characteristics between different voice samples, a rudimentary explanation of speech production is needed to understand the examination. The main organs involved in the production of speech are the lungs, trachea (windpipe), vocal cords, vocal cavities of the mouth, nose and throat, and articulators (lips, tongue, teeth, etc.) (Figure 1). Together, these organs modulate or change the air flow which begins in the lungs (Denes and Pinson 1973; Potter et al. 1947). This modulation can occur in four different, but interrelated ways that directly affect voice comparisons: start-stop, frictional, vocal cord and cavity.

Start-stop modulation, which can be produced by the vocal cords or articulators, is heard as relatively abrupt breaks in the speech flow, such as the very beginning of the sound "p." Frictional modulation is characterized by sounds like "s," "f" and "sh" (called fricatives) and is caused by air turbulence created by restricted articulators such as clenched teeth. Vocal cord modulation is the result of vocal cord vibration which rapidly interrupts the flow of air from about 50 to 500 times per second; this resulting buzz-like sound contains not only the fundamental vibration frequency, but a considerable number of harmonic overtones. In cavity modulation, the vocal cavities act together as a resonance chamber, suppressing some of the overtones produced by the vocal cords and to a lesser extent, frictional modulation; this process is like talking into a cardboard tube which changes the speaker's voice quality due to the specific resonant characteristics of the tube.

In normal speech, combinations of all four types of modulation are used. Stop, frictional and cavity modulations are combined to produce the sounds "p," "t" and "k" (called plosives), and all four are used in the voiced sounds "b," "d" and "g." When vocal cord, frictional and cavity modulations are combined, the voiced fricatives "z" and "v" are formed. In spectrographic analysis, the vowel and vowel-like sounds from vocal cord and cavity modulations are of the most interest.

SPECTROGRAMS

The most important device in spectrographic voice identification is, not surprisingly, the sound spectrograph which creates a visual graph (spectrogram) of speech

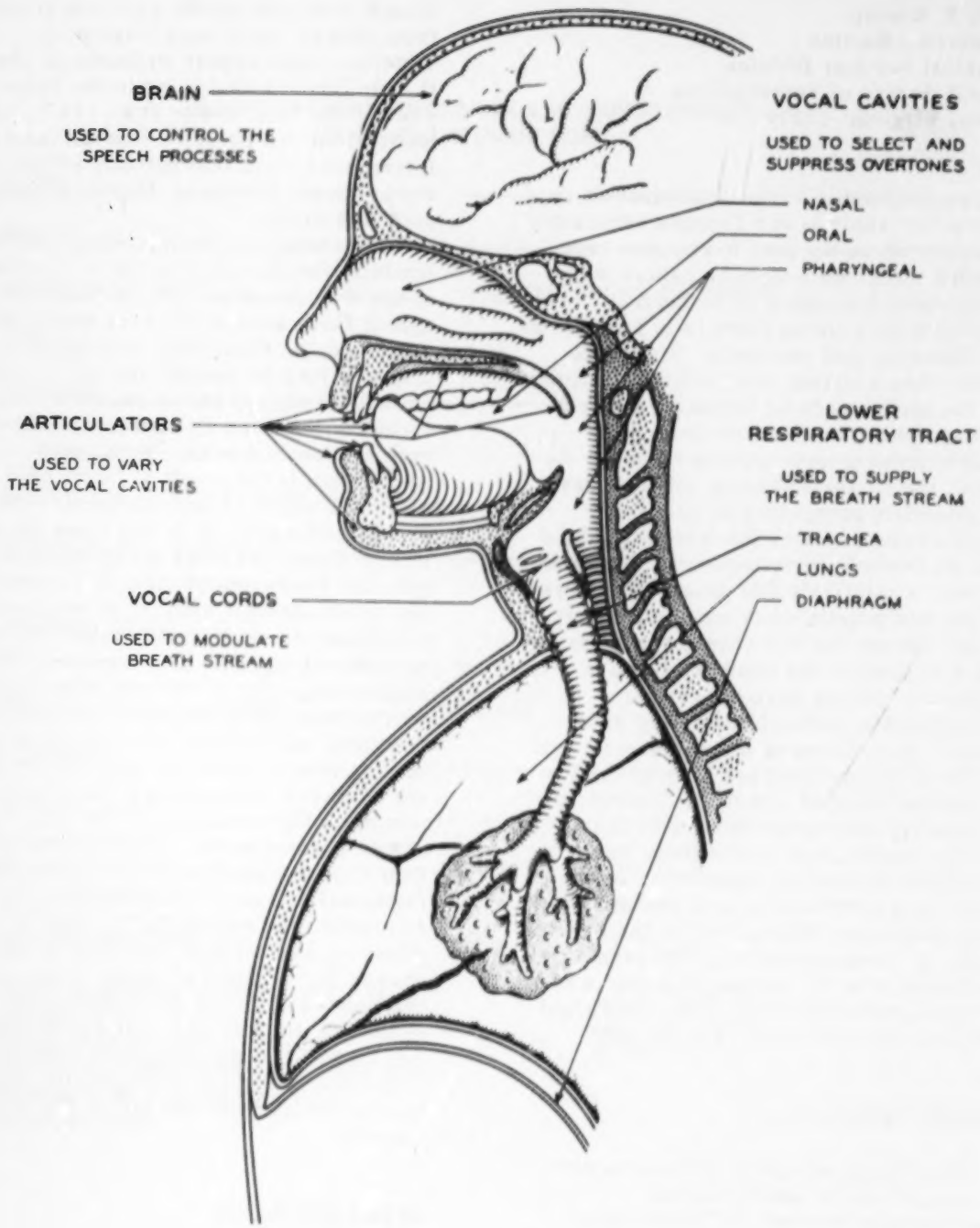

FIGURE 1. Schematic diagram of the basic speech processes (Potter et al. 1947). Reprinted with permission from Dover Publications, New York. All rights reserved.

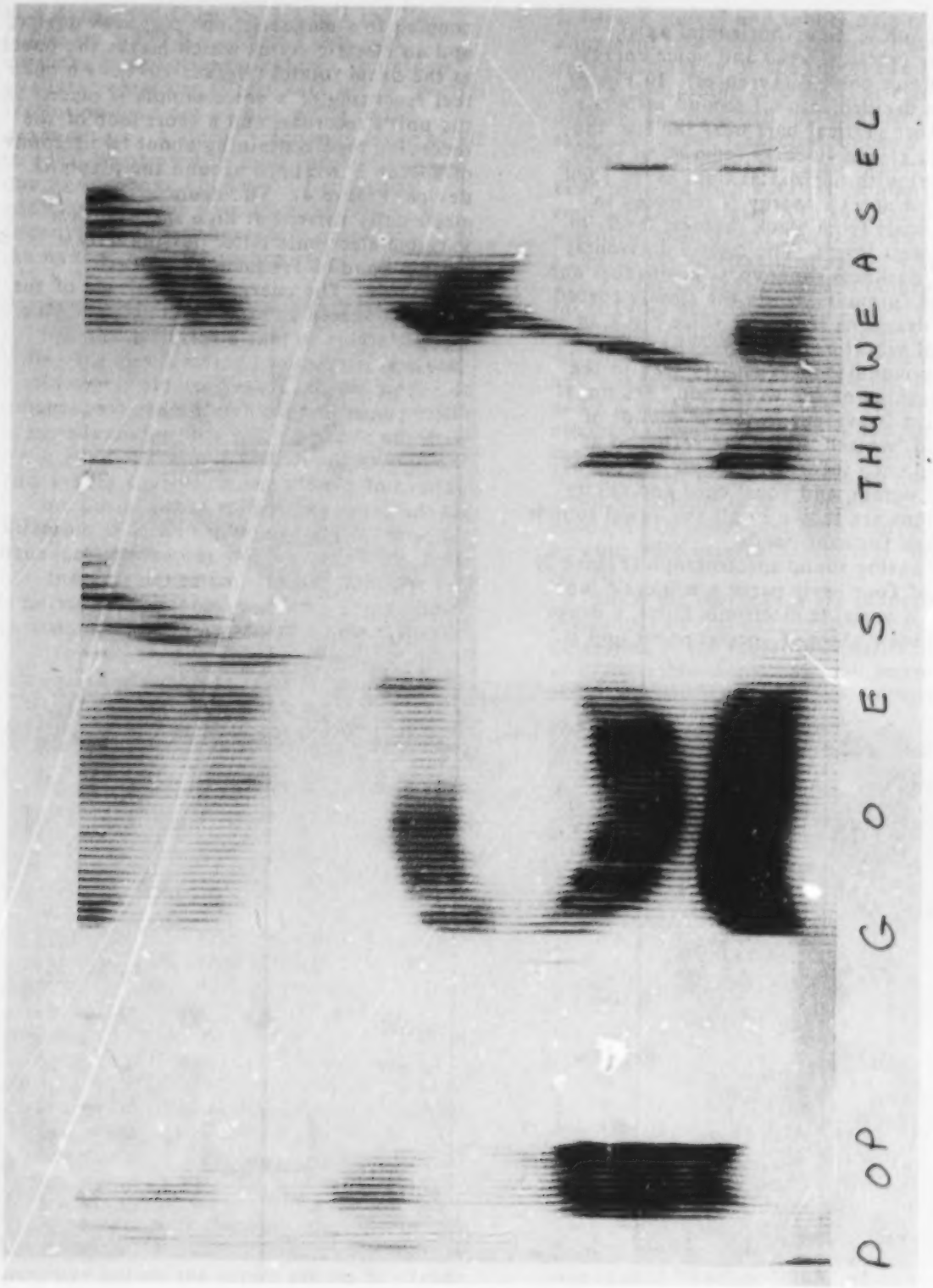

FIGURE 2. Spectrogram of "Pop goes the weasel."

as a function of time (horizontal axis), frequency (vertical axis) and voice energy (gray scale or color differences). In Figure 2, time is divided into 0.1 second intervals by the short vertical bars near the top, the frequency ranges linearly from 80 to 4,000 Hertz (Hz) with horizontal lines every 1,000 Hz, and the speech energy is reflected in the gray scale from black (highest level) to white (lowest level). The mostly horizontal bands of darkness show vocal resonances and are called formants, while the closely spaced vertical striations represent voice pitch, or the actual vibration of the vocal cords. Start-stop modulation is clearly seen in the very beginning of the word "pop," frictional modulation is evident in the "s" sounds of "goes" and "weasel" which are reflected as high frequency information near the top of the spectrogram, and vocal cord and cavity modulations are shown in all the vowel sounds as the dark formant bands.

The analog sound spectrograph (Figure 3) consists of four basic parts: a magnetic tape recorder, a variable electronic filter, a drum which holds a sheet of special paper and is coupled to a magnetic tape playback device, and an electric stylus which marks the paper as the drum rotates (Hecker 1971). An open reel recording of a voice sample is placed on the unit's recorder, and a short loop of the recording tape containing about two seconds of speech is wrapped around the playback device (Figure 4). The drum is then electrically rotated at high speed with a variable electronic filter passing only a certain band of frequencies on each revolution. The energy or amplitude of the recorded speech in each band activates the electric stylus so that a spiral of varying darkness is produced across the paper. As the drum revolves, the variable electronic filter passes increasingly higher frequencies with the electric stylus moving parallel to the axis of the drum (Figure 5). Thus, a pattern of closely spaced lines is generated on the paper to produce the spectrogram. Since a 300 Hz bandwidth filter is normally used, the fairly narrow resonance frequencies are widened and printed as the formant bands; for example, a resonance occurring at 1,000 Hz would be shown on the spectrogram

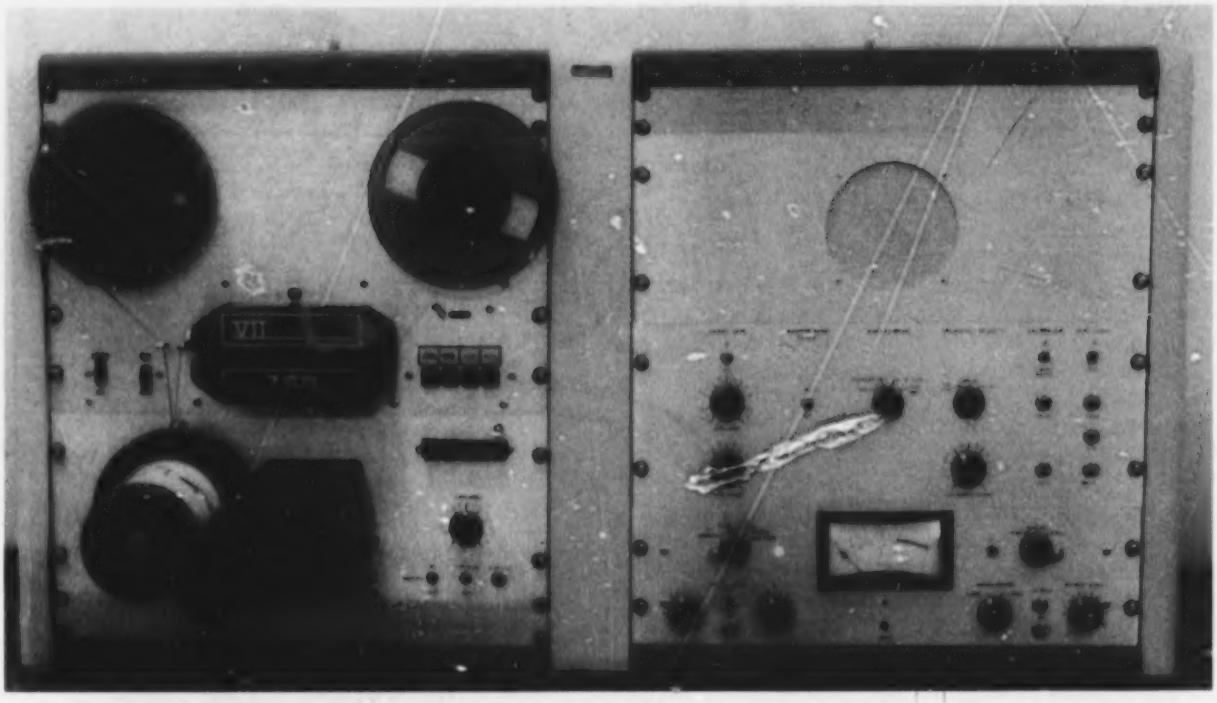

FIGURE 3. Analog sound spectrograph.

as a dark band from 850 Hz to 1,150 Hz (1,000 Hz ± 150 Hz). Since examiners compare gross formant features, the use of available narrower filters with better spectral resolution does not usually assist in the examination. A linear frequency range of 80 to 4,000 Hz is used in most forensic work, due to telephone bandwidth limitations; additionally, high shaping equalization is added by the spectrograph to compensate for the natural high frequency roll-off of speech.

FIGURE 4. Spectrograph drum with magnetic tape wound around playback device.

METHODOLOGY

Submission of tape recordings of unknown and known voice samples to the laboratory initiates the examination process. The first step after appropriately marking the recordings for identification is to copy them onto open reel tapes at 19 cm per second in a full-track configuration. Many examiners use the full-track tape recorder that is part of most sound spectrograph systems. To provide the best possible reel copies for examination, the azimuth and position of the track on the original recordings should be aligned with the playback unit and the recording speed checked and adjusted as necessary before the copies are made. Track configuration (i.e. 1/2-track monaural, 1/4-track stereo) and proper azimuth alignment (the correct placement and perpendicularity of the track) can be checked with a developing solution that visually displays the recorded information on the tape and allows inspection under a low power microscope (Figure 6). This insures that a tape recorder unit with the proper track configuration is used and that the playback magnetic head of the recorder can be adjusted for nonstandard azimuth alignment. The proper playback speed is determined by identifying and displaying known discrete frequency sources on the recording, such as AC power line leakage (60 Hz and harmonics) and telephone signals (touch-tone, busy, etc.) using a graphic Fast Fourier Transform (FFT) analyzer (Figure 7). Then if the speed of the recording is determined to be incorrect, it is adjusted by the use of high quality, speed adjustable tape recorders. Obviously, azimuth alignment and speed correction should be done with original recordings for the best results.

Once the reel copies are prepared, a preliminary aural examination is conducted to determine if the recording quality and number of comparable words meet minimum standards. If the quality is too poor, enhancement procedures using analog and/or digital filters and equalizers are sometimes tried in an attempt to meaningfully improve the intelligibility. If the quality cannot be improved sufficiently and/or there are too few comparable sounds, the examination is ended and the recordings are returned to the contributor with a request, if possible, for better voice samples.

If the voice samples have sufficient quality and comparable words, the actual spectrographic analysis begins. The sound spectrograph is employed to produce spectrograms of all similarly pronounced words used by both the unknown and known speakers. The spectrograms are marked phonetically while still on the spectrograph drum by denoting each spoken sound beneath its corresponding pattern. Since some words have different acceptable pronunciations or they are misspoken in the voice sample, the actual sound(s) used is carefully marked. For example, the word "the" can be pronounced "thee" or "thuh," and these pronunciations cannot be compared

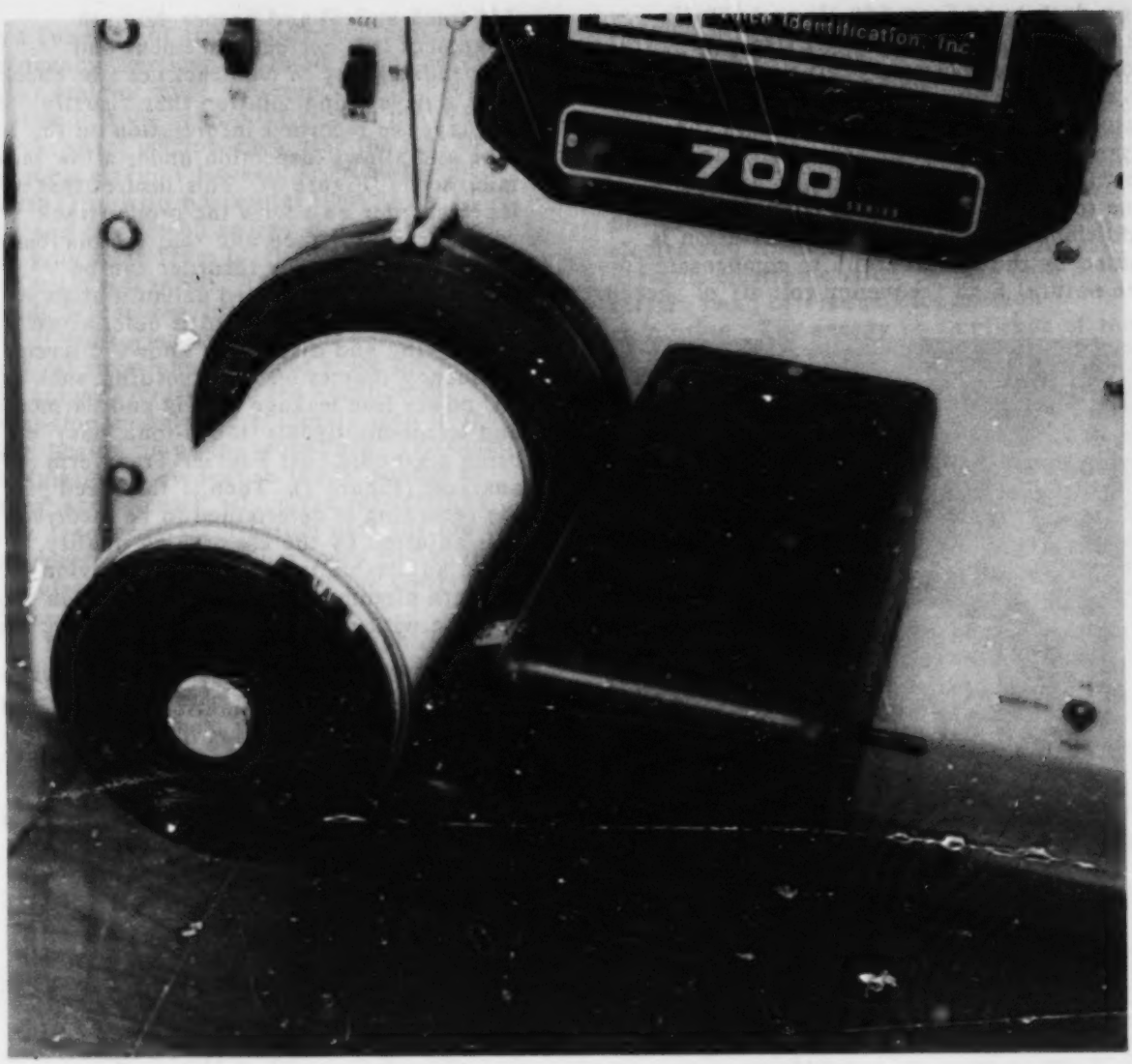

FIGURE 5. Spectrograph electric stylus printing on special paper on the drum.

spectrographically because they are different spoken sounds (Figure 8).

After all the spectrograms are produced and marked, the examiner makes a spectral pattern comparison between the same spoken words of the unknown and known recorded speakers. Characteristics compared are beginning, mean and end formant frequency, formant shaping, pitch, timing, etc. of each individual word. When available, similarly spoken words within each sample can be compared to insure sample consistency. Words with spectral patterns that are distorted, masked by extraneous noise, too faint or lacking adequate identifying characteristics are not used.

An aural comparison using high-quality headphones or loudspeakers is then made by repeatedly playing the two voice samples simultaneously on separate tape recorders or by playing similar words and phrases from the different voice samples consecutively on the same recording. Similarities and differences in accent, pronunciation, pitch,

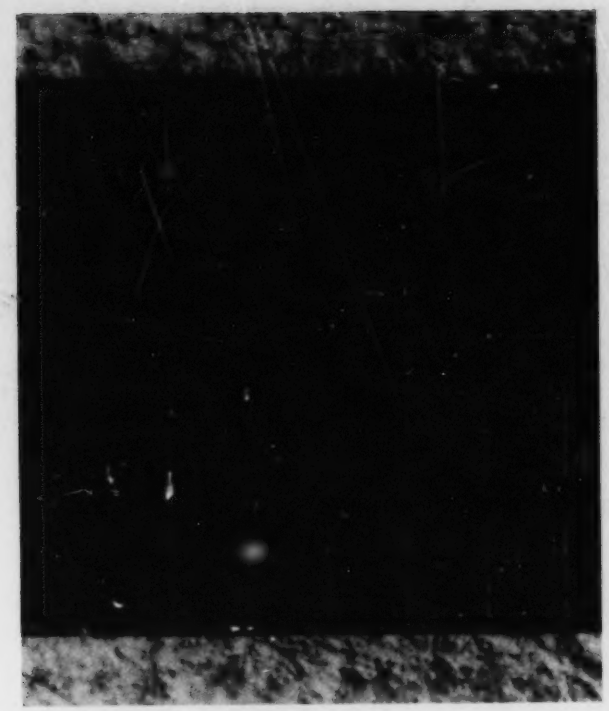

FIGURE 6. Magnified photograph of the recorded information on a cassette tape.

intonation, delivery, etc. are closely compared.

The aural-visual spectrographic examination requires the examiner to look for unusual patterns or speech characteristics that may be important clues for identification or elimination of the suspect. Since even the same word repeated by one speaker rarely has an identical spectral pattern (Figure 9), attempts are made to determine which dissimilarities arise from intraspeaker variability, indicating different utterances of one word by the same person, and which dissimilarities arise from interspeaker variability, indicating different speakers (Figure 10). Forensic applications have additional problems with voice disguise, limited bandwidth and signal-to-noise, telephone channel effects, altered psychological states, electronic manipulation, etc.

After a thorough visual and aural comparison, the examiner determines whether or not the two samples match and the degree of certainty of the results, i.e. possible, probable, etc. Obviously, comparisons can also be made between an unknown voice sample and a number of known voice exemplars or between two unknown samples when a sufficient number of comparable words are present.

SHORT HISTORY

Though speech spectrographs were developed in the 1940's (Koenig et al. 1946; Potter et al. 1947), forensic uses were not seriously considered until 1962 when Lawrence Kersta published the results of experiments which reflected error rates of 0% to 3% for one-word spectral comparisons (no aural) involving 12 or less speakers in closed sets (examiners always knew a match existed). In 1972, the findings of a large-scale study at Michigan State University (MSU), funded by the U.S. Department of Justice, were published which more closely imitated law enforcement conditions; however, again only

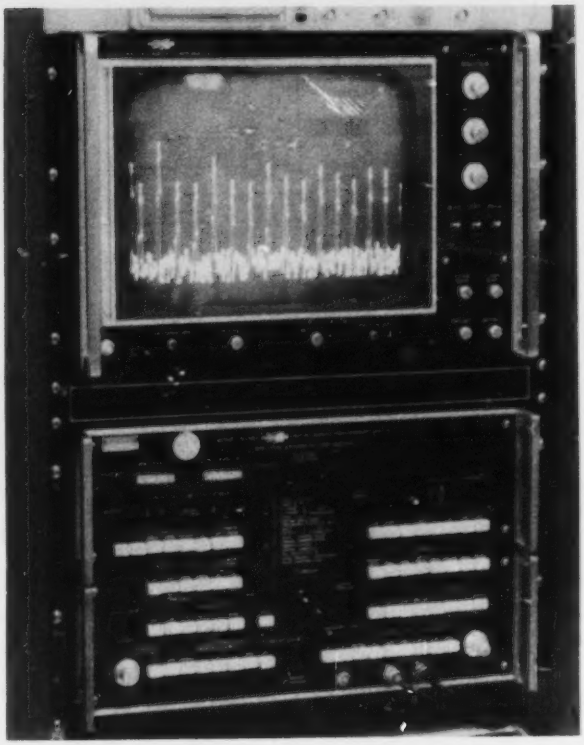

FIGURE 7. Fast Fourier Transform (FFT) display of a 60 Hz with harmonics signal.

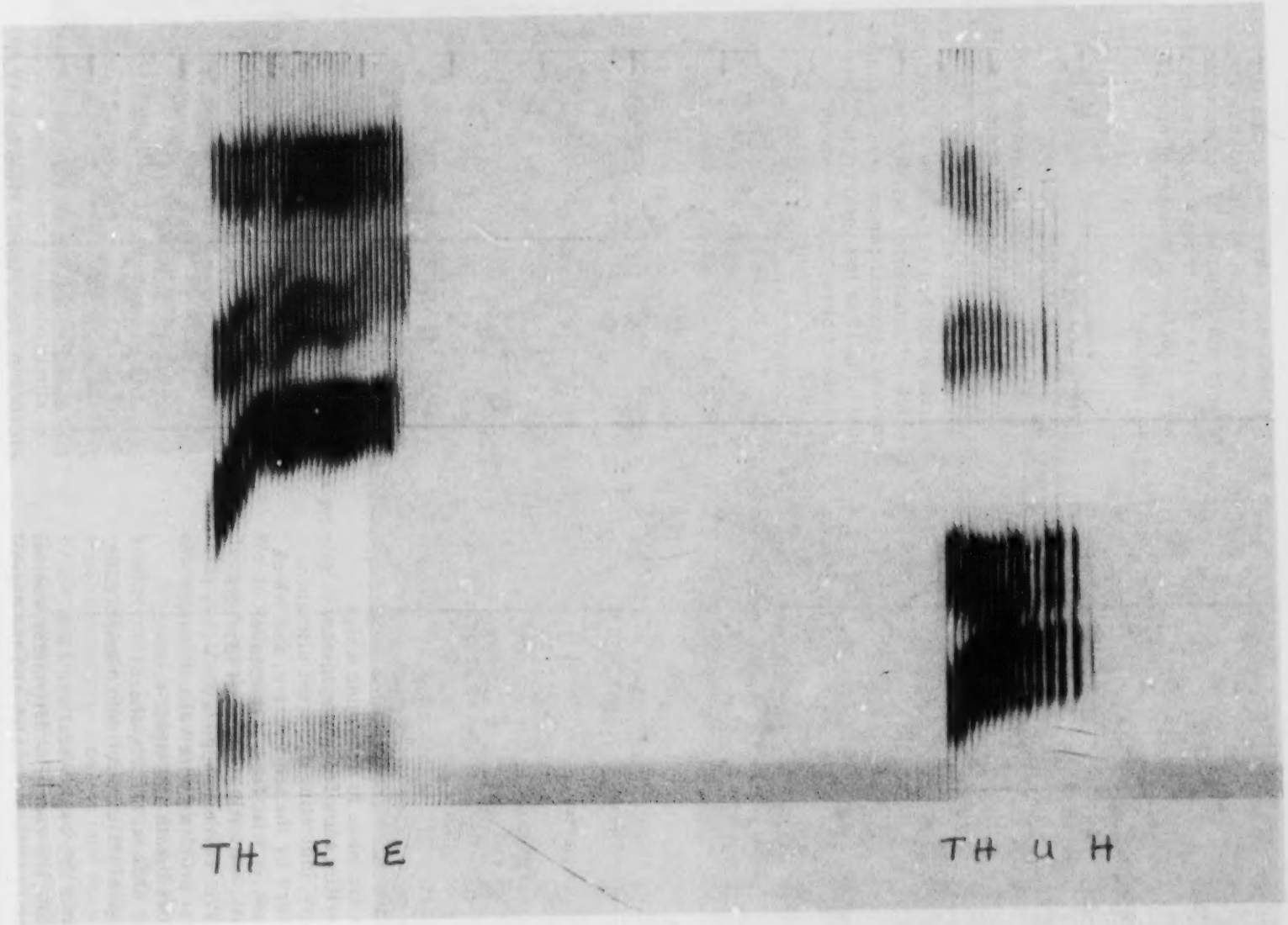

FIGURE 8. Spectrogram of one person using two different pronunciations of the word "the."

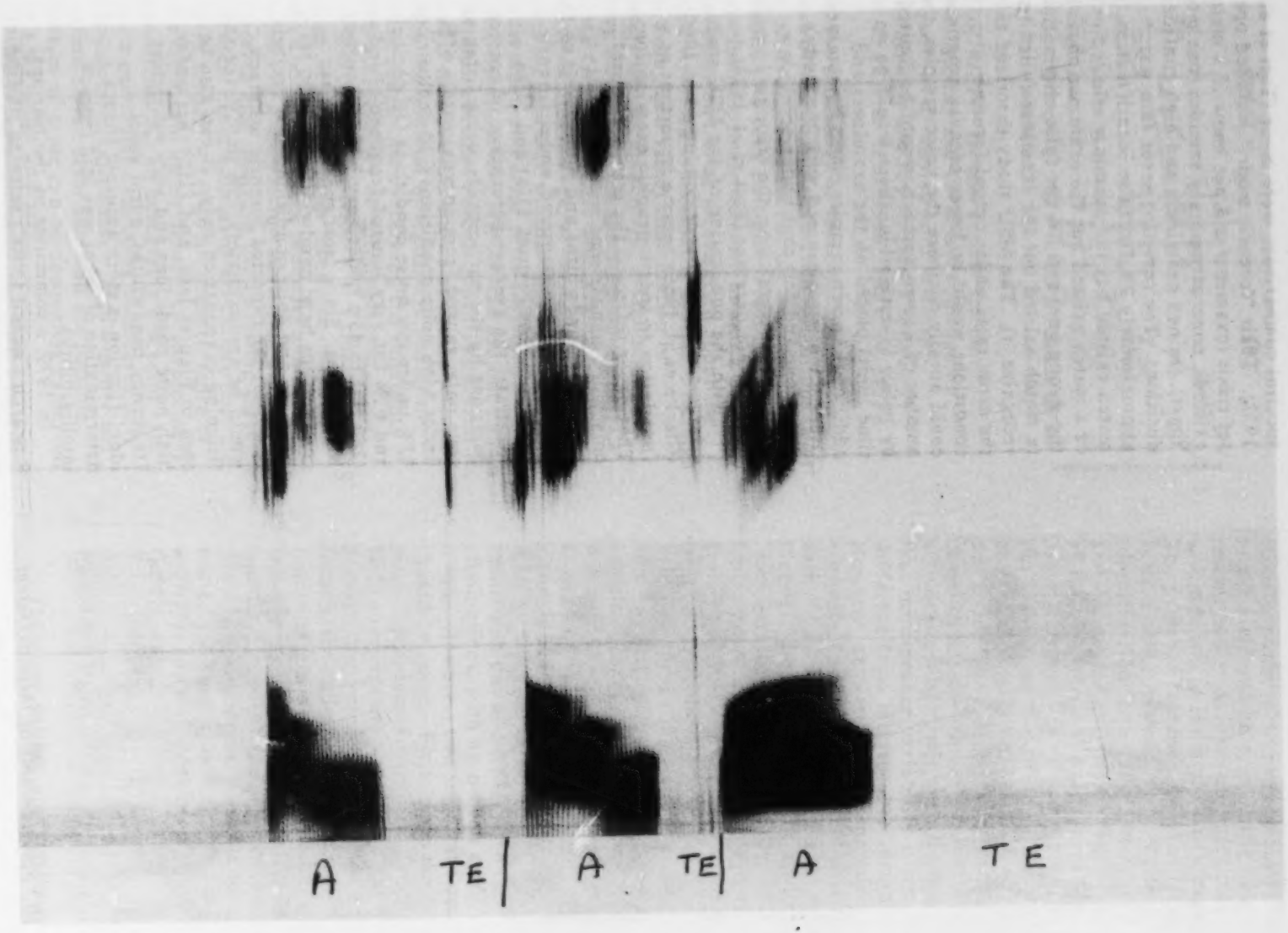

FIGURE 9. Spectrogram of one person saying "ate" three times.

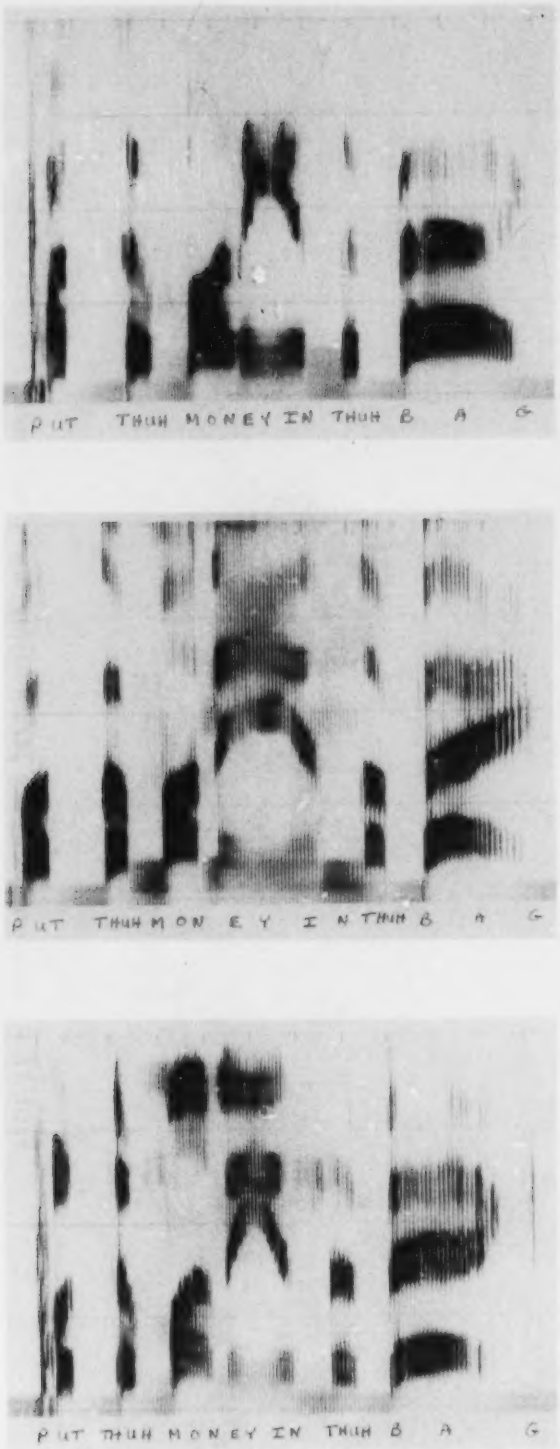

FIGURE 10. Spectrograms of three different males saying "Put the money in the bag."

spectral comparisons were made (Tosi et al. 1972). Their "forensic model" included open set trials (examiner did not know if a match existed), noncontemporary samples (one month apart), trained examiners and high confidence decisions. The resulting error rate was approximately 2% for false identification (no match existed but the examiner selected one, or a match existed but the examiner chose the wrong one) and 5% for false elimination (a match existed but the examiner failed to recognize it). The MSU study theorized that the error rates under actual forensic conditions would be lower because examiners could aurally compare the voice samples, the number of known suspects would be limited by police investigation, there would be no time limits placed on the examiners and additional known samples could be obtained. Other scientists disagreed with the study's extensions and felt that under actual law enforcement conditions, the error rate would increase, not decrease (Bolt et al. 1974).

With the publication of the MSU study, a large-scale experiment conducted in 1966 (Clarke et al. 1966) became important as a foundation to spectrographic examinations. That paper reflected the results of aural only voice comparisons with different frequency bandwidths and noise levels of the type normally encountered under forensic conditions. As Figures 11(a) and 11(b) illustrate, the average percentage of correct decisions by the participants, using listening tests only, ranged from approximately 65% under high noise conditions (-10 decibels) to 85% under low noise conditions (30 decibels) and 62% for very limited frequency bandwidth (250 Hz) to 85% under very wide frequency bandwidths. Since most spectrographic comparisons have bandwidths of 2,000 Hz to 3,000 Hz and noise conditions of 0 decibels or better, the expected forensic accuracy would be approximately 75% to 82% for the listening examination only. It can also be seen in Figures 11(a) and 11(b) that under high noise conditions and very restrictive frequency bandwidths, aural voice identification is more accurate than a determination of what was said (speech intelligibility).

In 1979, a committee of the National Research Council (NRC) released its findings and recommendations in an FBI-funded study

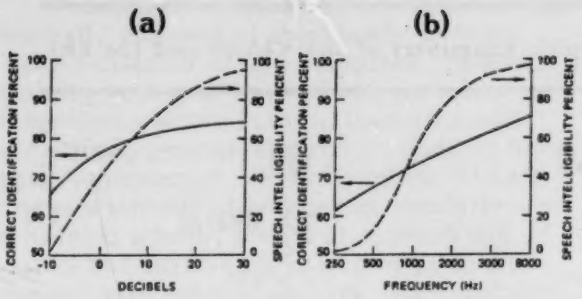

FIGURE 11. Percent correct speech intelligibility and aural identification as a function of varying noise levels in (a) decibels and (b) frequency bandwidth in Hz (Clarke et al. 1966; Bolt et al. 1979).

on the reliability of spectrographic voice identification under forensic conditions (Bolt et al. 1979). The committee separated its results into four portions: findings, conclusions, recommendations and a summary. It found that some information about the identity of an individual is available through listening and visual examination of spectrograms; fingerprint examinations are very different from spectrographic analysis since fingerprints are unchanging whereas spectrograms change, at least slightly, every time a particular word is spoken by the same individual; and error rates for voice identification vary widely and are not known for most forensic applications. The committee stated that there is not an adequate scientific basis for judicial or legislative bodies to make judgments concerning the reliability and acceptability of spectrographic comparisons. The NRC report concluded that some improvement in technique could be achieved by applying presently available technology, conducting additional long-term research and resolving the following three problem areas associated with courtroom use: there should be (1) an accurate measure of the error rate under actual law enforcement conditions, (2) an acceptably low error rate for a particular case being considered and (3) a determination made as to whether the nature of the error rate and the possible sources of error can be adequately explained to a lay judge and jury.

Recommendations of the NRC committee included that a coordinated effort be made to stimulate and guide basic scientific research in the field and an organization be established to develop objective standards and methods to test and certify examiners. The present organization in the field, the International Association of Voice Identification (now the Voice Identification and Acoustic Analysis Subcommittee (VIAAS) of the International Association for Identification) was not considered to possess the broad base of representation considered appropriate and essential for a national certifying board. In summation, the NRC committee stated, in part, that "the practice of voice identification rests on the assumption that intraspeaker variability is less than or different from interspeaker variability. However, at present the assumption is not adequately supported by scientific theory and data. Viewpoints about probable errors in identification decisions at present result from various professional judgments and fragmentary experimental results rather than from objective data representative of results in forensic applications."

In 1986, the results of a survey of 2,000 voice identification comparisons made by FBI examiners under actual forensic conditions was published (Koenig 1986). The report found that meaningful decisions were only made in 34.8% of the requested comparisons with an observed error rate of 0.31% for false identifications and 0.53% for false eliminations, with an overall error rate of 0.43%. However, two important conditions should be noted. First, since the error rates were determined from direct feedback from field investigators which may not always be correct, they represent minimum error rates; second, the educational and training requirements of the FBI examiners, the criteria for quality and quantity of comparable words and the sophisticated scientific procedures available to the FBI exceed the standards normally used and/or available to most other practitioners in the field.

PRESENT PRACTICE

There are neither universally accepted qualifications for examiners nor standard procedures used to make spectrographic

Table 1. Minimum Requirements for Spectrographic Examiners of the VIAAS and the FBI

Requirement	VIAAS	FBI
Education	None	B.S. Degree
Periodic Hearing Test	No	Yes
Length of Training	2 years	2 years
Number of Comparisons Conducted	50	100
Attendance at a Spectrographic School	Yes	Yes
Formal Certification	Yes	Yes
Periodic Recertification	Yes	Done Continuously

Table 2. Minimum Criteria for Spectrographic Comparisons for the VIAAS and the FBI

Criteria	VIAAS	FBI
Number of Comparable Words	10	20
Affirming Second Independent Decision	Yes	Yes
Original Recording Required	No	Usually
Allows Testimony	Yes	No
Verbatim Voice Samples	Usually	Usually
Speed Correction of Recordings	No	Yes
Track Determination of Recordings	No	Yes
Enhancement and Equalization	No	Yes

comparisons. The two most well-known sets of minimum standards are the ones used by the VIAAS and the FBI, as shown in Tables 1 and 2. Even though the VIAAS is the largest organization in the field, it does not represent many of the practitioners, and the FBI's standards only apply to its own examiners. Unfortunately, some practitioners have blatantly ignored all standards and criteria by conducting some examinations with only one-word comparisons, very poor quality samples, different languages on the two samples, no spectrographic training, etc. and then testifying in court to their positive, unrefutable decisions.

In the past twenty years, some federal and state courts have admitted the results of spectrographic examinations; others have not. Of course, how the results of the examinations have been presented in court has had an important bearing on admissibility. An examiner who is well qualified, meets accepted standards and gives a realistic evaluation of the technique's error rate is more likely to have the examination results admitted than a lesser qualified individual who overrates the technique's accuracy. It is noted that some practitioners only use the analysis as an investigative aid and do not provide expert testimony (Koenig 1980).

Training of spectrographic examiners has normally occurred in three ways: in-house, VIAAS-directed or self-conducted. In-house training is very effective in larger crime laboratories where fully trained personnel are already present, and strict standards have been implemented. Training by the VIAAS allows a structured program of regularly scheduled schools, review of examination results and regular telephonic or personal contact with other examiners. Self-conducted training is usually extremely limited, often with attendance at a few schools or seminars and minimal contact with other examiners. Research has shown that training and experience do lower error rates (Smrkovski 1976).

The present direction of the forensic spectrographic examination is obscured due to the relatively small number of active examiners, legal barriers to its admission in many jurisdictions, lack of generally accepted standards and the nonconclusive nature of the decisions. Past attempts to unite all spectrographic examiners and set universal standards have failed due to scientific, legal, philosophical and personality differences. The future for forensic spectrographic comparisons will probably lead in one of two directions: either to providing testimony using the FBI standards and the admission in court of a realistic error rate of approximately 1% (the FBI survey reflected a minimum error rate of 0.43%) or to severely limiting testimony and using the results principally as an investigative aid for law enforcement. As an indication of future changes, in September, 1986 the VIAAS was seriously considering upgrading some of its minimum standards for examiners and comparison criteria.

SUMMARY

Spectrographic voice comparison is a relatively accurate, but not positive technique for comparing an unknown voice sample with known verbatim voice exemplars. Present use of the technique is limited to a relatively small number of examiners who confront legal barriers to acceptance, limitations in accuracy and no universally recognized examiner qualifications and examination criteria. Its forensic future may shift to testimony where the judge and jury are advised of the technique's probable accuracy or to nontestimonial use as an investigative aid for law enforcement.

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ADDITIONAL SUGGESTED READINGS

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REGIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

A combined meeting of the Southern Association of Forensic Scientists (SAFS), the Southwestern Association of Forensic Scientists (SWAFS) and the Southwest Association of Toxicologists (SAT) will be held at the Baton Rouge Hilton in Baton Rouge, Louisiana from April 2-4, 1987.

The general program of this meeting concerns drug screening and will be devoted to plenary sessions and juried papers. Workshops are planned in the areas of serology, criminalistics and drug chemistry, and a panel will address the issues of proper testing, procedures, sample collection and interpretation of results.

The SAFS General Program Chairman is Jimmy Barnhill. He can be contacted at the North Louisiana Crime Laboratory, 1115 Brooks Street, Shreveport, Louisiana 71101 (telephone: 318-227-2889).

The SWAFS General Program Chairman is Adam Sobotka. He can be contacted at the DEA Regional Laboratory, 1810 Regal Row, Dallas, Texas 75235 (telephone: 214-767-7211).

The SAT General Program Chairmen are John Ricca and Glen Singletary. They can be contacted at the Louisiana State Police Laboratory, Box 66614, Baton Rouge, Louisiana 70896 (telephone: 504-925-6216).

The combined Spring 1987 Meeting of the California Association of Criminalists (CAC) and the Northwest Association of Forensic Scientists (NWAFS) will be held at John Ascuaga's Nugget Hotel in Sparks, Nevada from May 13-17, 1987.

For further information, contact Enrico Togneri, Washoe County Sheriff's Office, P.O. Box 2915, Reno, Nevada 89505 (telephone: 702-785-4637).

The Mid-Atlantic Association of Forensic Scientists (MAAFS) will hold their Spring 1987 Meeting at the Jefferson Sheraton Hotel in Richmond, Virginia from May 21-22, 1987.

The Program Co-Chairmen for the meeting are Rich Fortune and Robin Porter. They can be contacted at the Bureau of Forensic Science, P.O. Box 999, Richmond, Virginia 23208 (telephone: 804-786-4706 or 804-786-2281).

The Midwestern Association of Forensic Scientists (MAFS) will hold their Fall 1987 meeting on Mackinac Island, Michigan from October 6-9, 1987. This meeting will be hosted by the Michigan State Police Forensic Science Division.

For further information, contact Richard E. Bisbing, Michigan State Police Laboratory, 6296 Dixie Highway, P.O. Box H, Bridgeport, Michigan 48722 (telephone: 517-777-9300).

The Mid-Atlantic Association of Forensic Scientists (MAAFS) will hold their Fall 1987 Meeting at the Old Colony Inn in Alexandria, Virginia from October 15-16, 1987. Workshops are tentatively scheduled for October 14, 1987.

The Program Co-Chairmen for the meeting are Bruce Budowle and James Mudd. They can be contacted at the FSRTC, FBI Academy, Quantico, Virginia 22135 (telephone: 703-640-6131, ext. 3303 or 3899).

NATIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

The 39th Annual Meeting of the American Academy of Forensic Sciences will be held at the Town & Country Hotel in San Diego, California from February 16-21, 1987.

The theme of the meeting is "Biohazards in the Environment." Planned activities include plenary sessions and presentations of scientific papers.

For further information, contact the American Academy of Forensic Sciences, 225 S. Academy Boulevard, Colorado Springs, Colorado 80910 (telephone: 303-596-6006).

The 18th Annual Conference of the Association of Firearm and Toolmark Examiners will be held at the Downtown Seattle Hilton Hotel in Seattle, Washington from June 14-19, 1987.

Technical papers are requested for presentation at this meeting. Papers should be forwarded to Michael J. Grubb, Washington State Patrol, Crime Laboratory Division, 2nd Floor, Public Safety Building, Seattle, Washington 98104 (telephone: 206-464-7074).

For further information on the conference, contact Frank Lee at the above address.

The American Branch of the Electrophoresis Society will meet from June 23-26, 1987 at the University of San Francisco in San Francisco, California. Plenary sessions will include lectures on DNA, AIDS, agriculture and forensics. A workshop on DNA technology and isoelectric focusing is planned.

For further information, contact Bruce Budowle, FSRTC, FBI Academy, Quantico, Virginia 22135 (telephone: 703-640-6131, ext. 3303).

INTERNATIONAL FORENSIC SCIENCE ASSOCIATION MEETINGS

The Federal Bureau of Investigation will host a symposium entitled "An International Forensic Symposium on Latent Prints". The symposium is scheduled for July 7-10, 1987 at the FBI Academy in Quantico, Virginia. The symposium will provide a forum for the discussion of techniques and issues relevant to latent print detection, identification and automation. Plenary sessions will be devoted to lectures by prominent scientists on topics such as the composition of secretions that result in latent prints, how these latent prints are detected with dyes, lasers and other methods, automated fingerprint identification systems (AFIS) and quality assurance.

For further information, contact SA James J. Kearney, Symposium Coordinator, FSRTC, FBI Academy, Quantico, Virginia 22135 (telephone: 703-640-1181).

The Third International Symposium on Handwriting and Computer Applications will be held in Montreal, Canada from July 20-23, 1987. This multidisciplinary conference will cover topics related to research on handwriting and their practical computer applications in the fields of neural and motor aspects, experimental psychology, pattern recognition, man-computer interface, artificial intelligence, education, forensic sciences, computer aided design and instrumentation.

Scientific papers are requested for presentation at this meeting. Abstracts should be submitted by January 20, 1987 to Professor Rejean Plamondon, Laboratoire Scribens, Department de Genie Electrique, Ecole Polytechnique de Montreal, C.P. 6079, Succursale A, Montreal, Canada H3C 3A7.

The International Association of Forensic Toxicologists will hold their 24th Annual Meeting at the Banff Park Lodge in Banff, Alberta, Canada from July 28-31, 1987. Among the planned activities is a special session on "Postmortem Changes Affecting Toxicology."

Confirmed reservations are required. The deadline for making reservations is March 1, 1987.

For further information, contact Dr. Graham R. Jones, TIAFT 1987, 4070 Bowness Road N.W., Calgary, Alberta, Canada T3B 3R7 (telephone: 403-427-4987).

The International Association of Forensic Sciences 11th Meeting will be held at the Hotel Vancouver in Vancouver, British Columbia, Canada from August 2-7, 1987. The meeting will be structured around plenary sessions, short paper sessions, technical exhibits, poster sessions and an arts and crafts exhibition. Special presentations by the International Academy of Legal Medicine and Social Medicine and the International Study Group on National Unexpected Deaths are scheduled for the meeting. Plenary sessions include "Collection and Presentation of Evidence", "Conduct of a Criminal Trial" and "Sentencing the Offender."

For further information, contact the Secretariat, International Association of Forensic Sciences, Suite 801, 750 Jervis

Street, Vancouver, British Columbia, Canada V6E 2A9 (telephone: 604-681-5226).

The Third International Meeting of the Pan American Association of Forensic Sciences will be held concurrently with the First World Meeting of Police Surgeons and Police Medical Officers at the Holiday Inn Plaza in Wichita, Kansas from August 10-14, 1987.

For further information, contact Dr. William G. Eckert, P.O. Box 8282, Wichita, Kansas, 67208 (telephone: 316-262-6211, ext. 131).

INSTRUCTIONS FOR SUBMITTING ARTICLES

In order to facilitate rapid publication, submissions should conform to the following:

1. Manuscripts should be typed, double-spaced, on 8 1/2" x 11" paper. Submit three copies of the manuscript (one of which must be the original with glossy photographs).

2. Tables should be as simple as possible. Each table should be typed on a separate sheet of paper and should include a heading.

3. Graphs and diagrams should be submitted as sharp photographs on white glossy paper.

4. References in the body of the paper should refer to the author's (authors') name(s) and the date of publication. For example:

   According to Doe and Smith (1972)....

   ....has been discussed in the literature (Doe and Smith 1972; Weinburger et al. 1984; Jones 1981).

5. References at the end of the paper should appear in alphabetical order. Journal references should include the author's (authors') name(s), date of publication, title of article, journal name, volume number, and the beginning and ending pages of the article. Please use the following format:

   Davis, H. E. and Jones, B. A. (1978). Seasonal variations in plasma hormones, Biol. Reprod. 88:271-273.

   List articles or chapters within a book as follows:

   deHaseth, J. A. (1982). Fourier transform infrared spectrometry. In: Fourier, Hadamard and Hilbert Transformations in Chemistry, (Marshall, A. G., ed.) Plenum Press, New York, pp. 387-420.

6. Technical papers should be written in an Introduction, Materials and Methods, and Results and Discussion format.

7. When reference is made to a particular product, state the manufacturer of the product and the city and state of the manufacturer's headquarters. For example:

   Isotactic PS (Dow Chemical, Midland, MI)....

A

Accuracy in biochemical and
immunochemical tests, 25-27
Acquired immunodeficiency
syndrome (see AIDS)
Age
estimation of in adult and subadult, 38
AIDS, 1, 15
virus, 15, 21
Alligatoring
or blistering of wood in fires, 72, 75
Analog sound spectrograph
in voice analysis, 108
Antemortem radiographs, 42
Anthropology, 38-43
Antimony
analysis in GSR, 54-60
Archaeology, 42
Arson, 70
Aural examination for voice
identification, 109-111
Aural-visual spectrographic examination, 111
Automatic scanning energy dispersive
spectrometer
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B

Barium
analysis in GSR, 54-60
Biochemical and immunochemical tests, 25-27
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